Delivering Effective STEM Public Engagement

Improving schools outreach through enhanced understanding of school pedagogies and learning principles

National HE STEM Programme

Lighting up Learning

Produced by Nicholas Garrick, Lighting up Learning Limited, with additional material from Alice Ballantine-Dykes, Associate of Lighting up Learning Limited.
www.lightinguplearning.com

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Introduction

This guidance aims to enable staff, undergraduates, Masters and PhD students to develop their public engagement skills through understanding several key principles of pedagogy and practice from Key Stage One through to Key Stage Three.

This guide aims to enable STEM academics, from any STEM discipline, to undertake more effective outreach through a better understanding of current theory and practices with regard to school curricula and learning outcomes in the primary phase.

Its aim is to encourage reflection and dialogue between colleagues involved in designing and maintaining outreach opportunities. It provides tools and examples to evaluate current offers as well as plan and construct new offers using specific learning principles.

Staff, volunteers and students will be better equipped, and therefore become more confident, session leaders delivering engaging and effective outreach forming part of access agreements and public engagement offers.

In order to capture the outcomes of this project, it was decided that the journey would be documented as a guide in order to encourage sustainability both within the University of Bristol, but also other Higher Education Institutions. This guide in its entirety is the result of the funded project, and is divided into four sections:

- Part One: Past and Present
- Part Two: Understanding the primary phase
- Part Three: Leading the way with Earth Sciences
- Part Four: The Future of HE STEM

Materials referred to through this guide may be viewed on the HE STEM website and are available for you to use and adapt to assist public engagement in your setting.

(http://www.hestem-sw.org.uk/widening-participation/wp-projects/?p=16&pp=Enhancing+Public+Engagement+-+A+Guide)

Part One:

Past and present

A summary of policy and practice with reference to engaging young people and supporting teaching within STEM subjects

Over recent years the awareness of STEM subjects has increased as a range of research become public.

With findings from governmental policy, others from public, private and charitable organisations, this section aims to condense key messages with regard to the engagement of STEM and young learners, specifically looking at the apparent general decline in the take up of STEM subjects.

Children sometimes need 'switching on' to subject matter that they might find difficult or less interesting. However, even the trickiest mathematics or science can be delivered as awe -inspiring activities, experiences and investigations with the right guidance. Hopefully all schools do their best to inspire young people in STEM subjects, but all too quickly, even at Key Stages 3 and 4, we see nationwide interest and commitment to these subjects waning.

Over the past ten years the lessening interest in STEM subjects has led to fewer learners choosing them at GCSE level. According to Fazakerley and Richmond (2009), the percentage of pupils studying three separate sciences barely improved from 1997 to 2007, with all three subjects attracting 6% of pupils in 1997 and 8% in 2007. The picture at A-Level is more mixed, with Physics fairing a continued decline into 2010. Evidence from Ofsted and the Department for Children Schools and Families corroborate that pupils studying Biology, Chemistry and Physics are more likely to go on to study science at A-Level and degree-level.

The Policy Exchange Research Note (2009) states that: *'Since 1997 the percentage of pupils studying A-levels in Biology, Chemistry and Physics has fallen, which raises serious doubts about the veracity of any success claimed by the Government in promoting these subjects. The percentages themselves are all extremely low – in 2008 6.5% of students were studying Biology (down from 7.2% in 1997), 4.9% were studying Chemistry (down from 5.5% in 1997) and 3.3% were studying Physics (down from 4.3% in 1997)'.* (p.2)

Consequently there are fewer graduates in these areas – not least to go into industry and research – but importantly, fewer specialists returning to school to teach. However, 2011 saw a rise in the number of the number of pupils taking STEM A-Levels, but it is too early to state whether the overall trend of decline is reversing.

The following summary continues to outline the observations and efforts that have been made to raise the profile of STEM subjects across the sector.

Engaging young people from an early age

Young children, in the right environment, are naturally curious and questioning. Immersed in an activity that is relevant and challenging enough, young children will learn without realising it. Given the right experiences and role models, children will willingly engage in learning and be motivated to do so.

As children get older, having had first-hand experience and excitement in an area of study, it is likely they will invest further – finding out about work experience and apprenticeships, making choices about future employment and moving towards research and industry opportunities that STEM subjects offer. However, conventionally it would appear that mathematics and sciences in schools are not engaging young people to this degree:

'Young people turn away from science and mathematics in schools for many reasons – finding the subjects difficult, uninteresting or not relevant to their lives are key factors. It is in the interest of businesses who rely on STEM-skilled employees to help turn these negative perceptions around.' (CBI/EDI, 2010)

Past: Infrastructure and policy

Following the introduction of the National Curriculum, there appears to have been a significant shortage of STEM graduates entering the job market. The 2002 Roberts Review identified fewer students choosing science and engineering disciplines at University; the 2003 Lambert Review identified weak communication between schools, universities and industry and in 2004 Adrian Smith commented on the parallel decline of post-14 mathematics education. The questions: 'why was this happening' and 'what measures need to be put in place to reverse the trend?'

The Labour government responded by producing a 10-year innovation and investment plan for STEM subjects, and this is still being used to guide activity and policy around education, public engagement and opportunities for graduates in the workplace, despite a change in government. Over 200 organisations and individuals contributed to the Science Innovation and Investment Framework (SIIF 2004-2014). The ambitions for this policy included ensuring the UK maintained its centres of excellence for research in STEM subjects whilst producing a strong supply of scientists, engineers and technologists by achieving a step change in the quality of teaching and learning in STEM-related subjects at school.

As a result of this policy, there have been some dramatic changes in the infrastructure around activity in the classroom. At the forefront: STEMNET (www.stemnet.org.uk), set up to be a leader in enabling young people to achieve their potential in STEM subjects by enthusing them at school and by offering information about the career opportunities associated with these subjects. In addition they help schools and colleges to understand the range of enrichment opportunities available and encourage business and individuals to support young people in STEM by targeted use of resources.

STEM Ambassadors are volunteers of all ages working in a range of STEM-related roles from apprentice engineers to geologists, nuclear physicists to zoologists. Connected to (predominantly secondary) schools and colleges through STEMNET, they get involved in a number of ways that include: giving careers talks; helping out with STEM Clubs and running workshops in local schools.

In addition to this, a network of 10 regional Science Learning Centres (funded in part by The Wellcome Trust – www.sciencelearningcentres.org.uk) have been created to improve science teaching, enabling teachers to refresh and extend their skills and inspiring pupils by providing them with a more exciting, intellectually stimulating and relevant science education.

The Science Learning Centre's Primary Science Quality Mark Award scheme began in January 2010, offering the incentive and framework for schools to improve the quality of science teaching and learning, extending the breadth and richness of the science curriculum and stimulating teachers' and children's excitement in the subject.

Each annual report on the SIIF 2004-2014 policy reflects that there has been progress made on some of their key goals: entries for Mathematics, Chemistry and Physics A-Level have significantly increased; the 14-19 Diploma for Engineering was the most popular of 5 diplomas introduced in September 2008; and expert groups have been formed in science teaching and learning to provide advice on how STEM studies can be developed into careers (Next Steps, 2006; Annual SIIF review, 2009).

Despite policy informing progress of this kind, there are still considerable gaps in the supply and demand of STEM graduates. Lord Sainsbury's 2007 report, *The Race to the Top: A Review of Government's Science and Innovation Policies*, recommended a major campaign to enhance the teaching of science and technology, focusing on what could be done in schools to raise the profile of the subjects and to generate a new wave of interest and commitment to these areas beyond school.

The review also believed that there was a major need to improve the level of career advice given to young people, so that they are aware of the exciting and rewarding opportunities open to those with science and technology qualifications. The website 'Careers from Science' (www.sciencecouncil.org/content/careers-science) offered by The Science Council was applauded and the concept of a National Science and Engineering Competition, which has since been devised under the name 'The Big Bang', started as a result of this report in 2009.

PRESENT: Starting Early

All STEM subject areas at Primary could play a role in developing a range of interests and skills, transferable across the curriculum. The content of STEM-related curricula is ripe for a range of really exciting and engaging learning opportunities for young people of all ages. The earlier they start, the earlier young people will get hooked on the potential of STEM subjects: for interest, work and fun.

A report produced by OFSTED in 2011, '*Meeting Technological Challenges? Design and Technology in Schools 2007-2010*', comments on the basics of good teaching and learning in design and technology.

'Pupils enjoy designing and making, solving problems and seeing their ideas take shape. Design and Technology (D&T) has a positive impact on pupils thinking, problem solving, creative skills and personal development'.

The report found children's experiences of designing and making in the Early Years Foundation stage were encouraging, with children making good progress in developing expertise. Features of a good primary curriculum include: good planning; challenging activities; links with external partners; high levels of knowledge and understanding and technical skills.

However, whilst Design & Technology is still a popular subject choice at Key Stage 4, numbers entered for examinations are dropping. Continuity and transition between phases, especially Primary through to Secondary, requires continual investment to ensure the interest and commitment to design and technology, and all STEM subjects, remain high.

Maintaining Smooth Transitions

If creating exciting STEM opportunities in the Primary phase is to be sustainable, then there needs to be attention as to how these subject areas develop throughout the educational phases; it is nonsensical to think that perceived inadequacies of one phase will be made up for elsewhere in the system.

A review produced by The Confederation of British Industry and Education Development International (CBI/EDI, 2010) entitled 'Ready to grow: business priorities for education and skills' is clear: STEM subjects must become a priority in schools. In the long term, three out of four businesses (72%) rely on people with STEM skills, yet the current supply of STEM graduates is not meeting business needs.

'Only 16% of UK undergraduates are studying physical sciences, technology, engineering or mathematics. And the UK has seen a greater decline in the proportion doing these valued subjects than many of our OECD competitors.' (CBI/EDI, 2010)

Relevance of STEM: informing subject choices

At over £2 billion in global sales, the UK's video games sector is bigger than either its film or music industries, and visual effects, the fastest growing component of the UK's film industry, grew at an explosive 16.8 per cent between 2006 and 2008. However, this industry, though still enjoying very rapid growth, is having to source talent from overseas because of skills shortages at home.

Outlined in a report by NESTA (National Endowment for Science, Technology and the Arts; Next Gen, 2011) these industries suffer from an education system that does not understand their needs. '*This is reinforced by a school curriculum that focuses ICT on office skills rather than the more rigorous computer science and programming skills which high-tech industries like video games and visual effects need. At the same time, young people and their teachers need a greater awareness of the job prospects in these industries and the qualifications that can take them there. STEM subjects and art are key to success*.' (p.5). NESTA demonstrates that the current curriculum for STEM subjects, let alone how it is assessed and taught, is out-of-step with the needs of related businesses; they believe it is out-of-date and not fit–for-purpose.

Making learning relevant is the job of all schools, but it is also the responsibility of the business community to help schools identify how industry is changing, to respond accordingly. A good example is The Greenpower Educational Trust (www.greenpower.co.uk). Their vision: to inspire young people to become engineers, demonstrating the importance of engineering, and associated STEM subjects, to solve the problems faced by societies today.

Greenpower offer kit cars to groups of school children that, with their help, build the car for top performance. They even get a chance to race their cars against other groups at Goodwood Racecourse. This business-driven initiative enables schools to engage with local industry, other schools (including making links between primary and secondary), all whilst learning about the relevance of their design and technology curriculum and other issues around sustainability and STEM-relevant subject areas.

Supporting Teaching

A key feature in the development of such business links with schools is the leadership of heads and teachers to nurture such projects and relationships. *'More than a third (36%) of the employers CBI/EDI surveyed believe government should free-up teachers from curriculum constraints to allow them to inspire students. This action is seen as necessary to ensure teachers can deliver exciting lessons which inspire young people to study science and Mathematics, rather than purely focusing on getting through the required learning before assessment*.' (p.36)

STEM subjects are often managed discretely in schools, particularly secondary, and such organisation disguises potential interconnectedness; industry needs creative thinkers but curriculum may be creating lasting barriers that cloud innovative thinking. Content-driven assessment also limits enquiry-based or practical investigation, which means that the curriculum does not really allow educators or pupils to get to the heart of the type of work that STEM subjects can offer.

Advice about the value of STEM subjects should also be reconsidered. Indeed, 'Mathematics is identified as *particularly valuable for some sectors, selected as the top choice by 30% of employers in manufacturing, rising to 47% in construction. In the science and advanced technology sector, the single most favoured choice of A-level is physics or chemistry (28%).*' (P.24, CBI/EDI (2010)).

However, making subject choices at school is not as free as the business, or Higher Education, community might think: it can often be issues of timetabling that prevent students from studying certain subjects together. Schools timetables may not allow for the combination of subjects that would enable real innovation in some STEM - related occupations.

Employability

'*Employability skills are the top priority for business when recruiting graduates from any discipline but worryingly businesses are finding that STEM graduates are not demonstrating these important skills*.' (p. 35 CBI/EDI, 2010)

In order to address some of these skills shortages, the CBI/EDI suggests that schools embed these types of skills within the curriculum, rather than favouring knowledge and content in order to pass tests. The skill set includes: self-management; teamwork; problem solving; communication and literacy and the application of numeracy and information technology. Indeed, one way to develop these skills would be through a greater range of vocational options; '*too often in the past… neglected relative to more obviously academic subjects and have been seen as less worthwhile by many involved in education*.' (p. 11 CBI/EDI, 2010)

Work experience is also particularly valued by business as 'crucial in helping the transition from education to work'. Two thirds of employers (65%) believe gaining practical experience is the most valuable step young people can take to improve their prospects. If this is so, then the links between education and business, already cited in the SIIF (2004-2014) policy as key, must become stronger for businesses to be able to design work experience and vocational options that are relevant, sustainable and effective.

Historic Barriers

Another area flagged up by the SIIF 2004-2014 report concerns for those students who suffer various cultural barriers to studying STEM. These largely focus on issues of gender and ethnicity. According to the UK Resource Centre (UKRC), in 2008 there were 674,000 women in STEM occupations and 4,823,000 men. Women were 15.5 percent of the workforce in STEM occupations and only one per cent in STEM-skilled trades.

Part Two:

Understanding your target audience

A brief introduction to whole school and classroom practice from Early Years & Foundation Stage through to Year Six

This section provides a general overview of the current primary system. It briefly explains pedagogies and approaches to learning as well as the emphasis on skills development and how the primary National Curriculum is changing.

The complexities of curriculum

Although all schools have a statutory requirement to follow the National Primary Curriculum 2000 (NC2000), each school has the autonomy to deliver the statements within it in the most appropriate way to suit the needs of their learners. Schools will adapt the NC2000 according to their needs, priorities and context. As a result, this package focuses on supporting session leaders to understand general principles of teaching in the primary phase, whilst using illustrative examples from the Earth Sciences making some references to Earth Sciences where needed.

Most primary schools use an integrated or linked approach to NC2000 subjects often resulting in the teaching of projects, or enquiries, that meet a variety of learning outcomes, not specific objectives. This approach is based on making active and purposeful links between skills and knowledge in specific subject areas and bringing them together to form engaging and purposeful experiences.

Consequently, one cannot assume that because one school has chosen to study volcanoes, another local school will. It should also not be assumed the children will only learn about volcanoes in a geography or science context. Teachers are very adept at cross-referencing and enriching content with context. For instance, children may spend a day immersed in learning about volcanoes, so that for the next three days, they can write accurate and technically correct texts as part of the literacy curriculum, e.g. discussing why a volcano could not suddenly appear in Bristol City Centre. **The variety in approach to the curriculum affects the way that public engagement offers should be tailored. They should be based on pedagogic theory complemented by rich content, enhanced by the facilitation of highly knowledgeable people.**

Engagement offers should not, therefore, reference specific objectives of the NC2000, but focus on learning outcomes – what will be achieved by engaging in such activities. It is up to a school to ensure coverage of the NC2000, not external providers.

Schools have a statutory requirement to enable children to acquire specific knowledge and understanding of the world that is relevant to the work of STEM. For example: how the properties of materials differ and how they change state.

Key pedagogy in the primary phase

'Pedagogy' refers to principles that underpin teaching and explain the ways in which educational goals may be achieved, why we teach certain things and in certain ways. Alexander (2000) refers to it as encompassing *'the performance of teaching together with the theories, beliefs, policies and controversies that inform and shape it'*. The term relies on educational psychology or theories about the way in which learning takes place. Despite every school having its own ethos and values, most teaching follows a similar set of principles that inform the way the curriculum is mapped to the type of questions asked.

Interpreting the National Curriculum

Most primary schools operate a three or four phased approach to curriculum mapping and delivery. When the National Curriculum was first introduced in 1988, two stages emerged. Key Stage One includes Year One (5-6 year olds) and Year Two (6-7 year olds). Key Stage Two includes Years Three (7-8 year olds) to Six (10-11 year olds). These are preceded by the Early Years and Foundation (EYFS) stage and followed by Key Stage Three and Four in secondary school.

Attainment of pupils varies widely from school to school depending on a range of factors. These will influence the way in which schools interpret and package the NC2000. Consequently, schools adopt different approaches to school organisation in which children are grouped within phases. This enables a more flexible approach to curriculum coverage.

'Every important idea in science sounds strange at first.'

- Thomas Kuhn
Physicist and Philosopher

The most common phases of learning are:

- **Early**: Early Years & Foundation Stage, Year One and Year Two
- **Middle**: Year Two, Year Three and Year Four
- **Later**: Year Four, Year Five and Year Six

Year Two and Year Four would sit in one phase, not two as listed above. Individual schools decide where the most suitable placement is according to the needs of the learners, such as standards in literacy or speaking and listening.

Increasingly, schools are re-discovering the power and flexibility of the NC2000 and are moving away from a prescribed interpretation known as QCA Schemes of Work. However, there have been many reviews of the National Curriculum over recent years, including one being undertaken by the current coalition government. **With this in mind, it is even more important to stress that public engagement should focus on learning outcomes and not lists of objectives.**

Developing awareness of the world

Each phase correlates with a child's growing awareness of the world around them. Younger children focus on the world immediately around them, but for older children in the later phase, they have a more established sense of global issues that affect society.

This understanding of awareness will affect their ability **to understand key concepts and should inform the language and nature of activities that they engage in during sessions.** For instance, there is little point in speaking to a Year One child about why people do not live in a lava flow path of a frequently erupting volcano. They will simply want to know (and see, feel and hear) one erupt – albeit a model in a playground.

Age and concentration

It is commonly accepted that there is a correlation between age and concentration, although there are many equations and factors to consider.

A younger child's ability to concentrate is non-linear; therefore, in the early phase (four to six years old), a child could concentrate fully for a period of minutes equivalent to their age. On a good day when learning conditions are positive and engaging, it could be anything up to three times their age, but rarely more than that. Within this phase, **session leaders should talk for no more than 10 minutes at a time, punctuated by 20 minutes for a physical and practical activity.** Depending on whether the activities require a lot of intellectual input or not, the time that children are able to stay engrossed in an activity will vary. Teachers will be happy to advise.

Children of the later phase, have relatively matured brains and can listen and pay attention for up to half an hour in a very good learning environment. Their ability to get on with an exercise once it has been explained is now of equivalent duration to the input, as long as there is plenty of opportunity for discussion, group talk or physical activity.

Stages of learning

Many primary schools use the Learning Cycle or something similar to plan and construct effective learning opportunities.

This can be used as a planning tool, ensuring that needs of different learners is considered (visual, kinaesthetic and auditory) as well as how to engage and challenge them. This is particularly important if the content of the session is complex, either conceptually or in language.

Session leaders could use the Learning Cycle (as seen on the following page and in the appendix) to plan out the different types of learning opportunities that may feature and it is considered good practice to include all aspects of the cycle where possible.

The Learning Cycle

WOW events enable practitioners to consider how they are going to hook the children, and excite, enthuse and engage them.

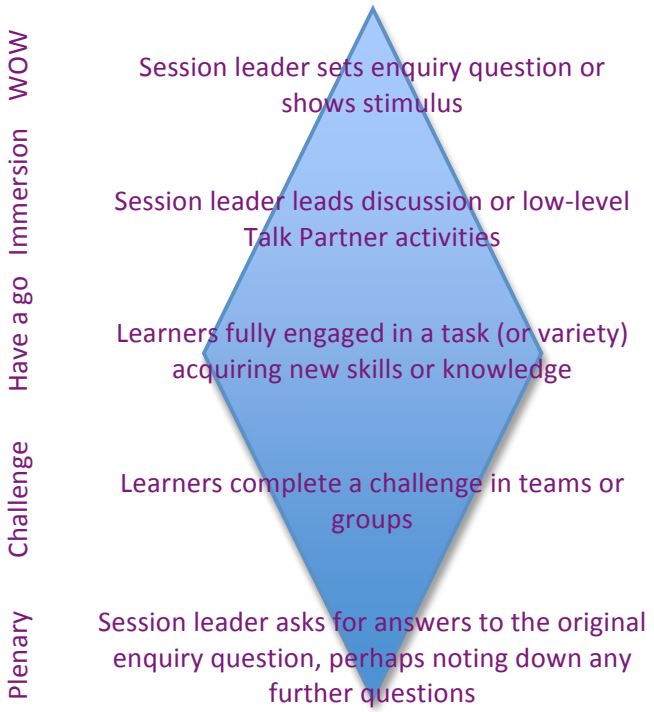
Immersion gives quality and protected time to think. Learners engage in sense-making practices, particularly if complex language is involved. This could be matching technical vocabulary to descriptions of volcanoes, or describing what an eruption may be like through imagery.

Having-a-go allows learners to do just that. The stress of getting it right first time is removed. They are given a range of experiences and activities that allow them to structure their thinking. This is traditionally where most of the 'learning' happens and could be the main focus of a session.

Equally the inclusion of a **challenge**, event or outcome of some sort, enables all to see what the learner has drawn from the process. Pretending to be a Geologist and explaining to everyone what is happening in the image; designing a lava-safe vehicle, or engaging in a volcano quiz in teams, all provide opportunities to demonstrate newly acquired skills, knowledge or understanding.

Using the Learning Cycle as a planning tool can also help with the delivery of sessions. Chunking the session into sections will help keep pace, add variety and ensure that any one activity does not overshadow others. It also ensures that the session is closed appropriately and not just severed by "any more questions?".

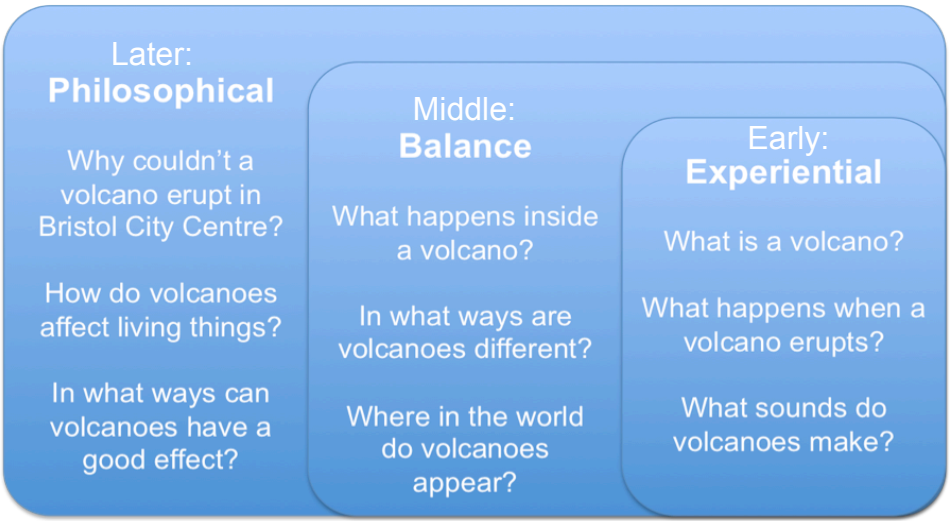
An effective, generic session structure could be thought of as a diamond. **Starting with the session leader explaining why they have come today and what type of things the learners may be asked to do. The activities increase in duration and participation as the children become more familiar with the content, slowly draw to a close with a plenary or verbal summary.**



It is worth noting, that any new face entering a classroom is exciting for learners and there will be a lot of energy. **It may be helpful to ask the teacher what strategies they use to bring the children together.**

The importance of questioning

At the time of writing, there is a national drive to promote and encourage active, multi-skilled learning. Many schools are already doing this through an enquiry-based approach. The use of questions instead of titles to stimulate learners has a dramatic affect on engagement and questioning skills. Learning projects, or enquiries, usually have a question that children try to answer by the end of the session or project. This is very powerful and has great results. **It is highly recommended that session leaders do this and ensure that they take into consideration a child's developing awareness of the world (page six).**

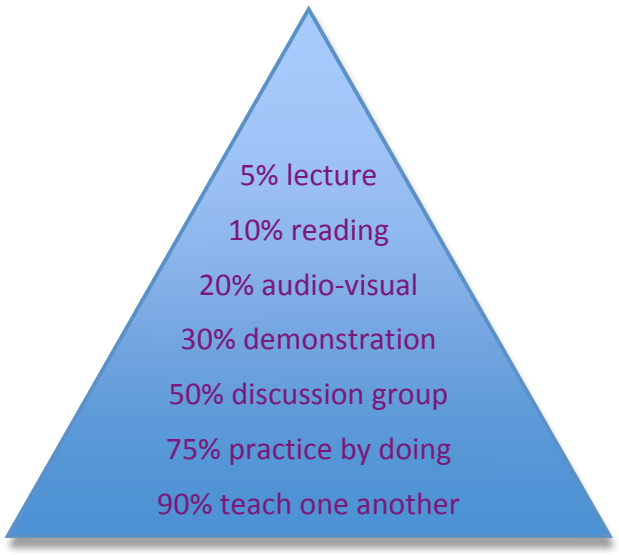


The question should link to the challenge and children should be able to answer the question (or at least in part) by the end of a session or project. Closed questions should be avoided as they can repress enquiry-based learning, whilst open questions yield better discussions and, hopefully, further questions. Questions that start with 'What', 'When' or 'Where' are particularly useful. **'How' and 'Why' questions should be saved for the later phase, as they require more complex answers that usually involve explaining a concept or use of technical language. This is very challenging for a younger child.**

It is equally important to consider why we ask questions. It is not necessarily to get an answer right or wrong, although direct, closed questions do have their place. It is primarily to get people to make connections. **Therefore, a really good strategy to get children thinking is to ask them to come up with questions at the start of a session that they would like answered by the end.** This could be done in pairs or small groups with examples of questions clearly displayed. Having generated a variety of questions, the whole group could make links between them: are there any repeated or similar questions? Could questions be combined to become more accurate or precise? Could questions be grouped into categories: primary sources, secondary sources, fact or opinion? **This is a valuable exercise to do with a group you do not know, as it will indicate if they are particularly inquisitive and will determine how much prior knowledge the children have informing the session.**

Critical skills are one way of developing active, seeing, thinking learners. They are not a strategy or initiative rather, a set of principles and techniques that open up teaching and learning to enable in-depth discussion, complex language and team work.

The critical skill toolbox can really help to promote enquiry-based learning in public engagement sessions. The toolbox is an approach where the 'teacher' behaves more as a coach, saying little and encouraging the learners to talk. This is not to say that one can never talk for an extended period of time; session leaders still need to convey key concepts, but should keep 'age = concentration' in mind. Engagement sessions should be about learning not teaching. The learning pyramid below demonstrates the amount of information retained by a developing mind through certain activities.

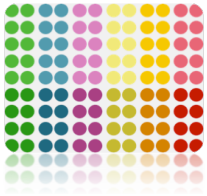


These are the common characteristics of a session that feature critical skills, as cited in the *Critical Skills Handbook - tools for the EBD classroom (2006)*:

- Learners frequently work as a team
- Learners actively solve meaningful problems
- Learners publicly exhibit their learning
- Learners reflect on what they are learning and doing
- Teachers mediate, coach and support the learning process
- Work is interconnected
- Learners take responsibility for, & ownership of, their learning & for the classroom community

Despite critical skills not being used by all schools (there are plenty of alternatives available), the common approaches on the following pages aim to develop curious and creative learners able to make connections, ask pertinent questions and critically evaluate.

Tools for developing an active environment



No Hands up

Some children will always put their hand up to answer, others never will. Using children's names directly is a simple but effective way of drawing different children's ideas out. Ask the school if it is possible for the children to have name labels. Alternatively you could use coloured dots: *"I wonder if anyone with a blue dot could have a go at answering?"* The dots could then be used a form of grouping: *"Could all the orange dots form a group and decide what the answer may be?"*

High Quality Audience

Children in most schools will respond immediately, when an adult says: *"Please may I have a high quality audience in 3, 2, 1…"* They understand this means stop talking, face the speaker and listen. Alternatively, ask the teacher what their stop sign or phrase is.

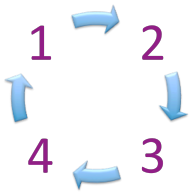
Talk Partners

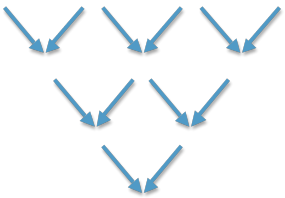
Commonly used in schools, the use of Talk Partners ensures that all children have an opportunity to formulate and share ideas before answering. On asking them to 'turn to their talk partners' children will usually physically turn to face their partner and begin talking almost immediately. This opportunity to focus on what an answer might be is particularly important if there are several children in a group with low levels of literacy, such as English as an Additional Language or Additional Needs.

Tools for whole group discussion

Carousel

Imagine three or four tables each with objects, images or questions and a different coloured pen. Groups of children start at one 'station', or table, answering questions or noting ideas. Then after 2 - 5 minutes the session leader asks the children to move around the room onto the next station, taking their coloured pen with them where they can add more or tick if they agree with what has already been written. This is repeated until all children have visited all stations.





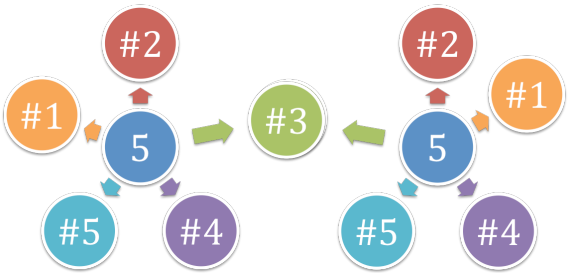
Distillation

Children start off in pairs or small groups to arrive at an agreed, single response for the group to a question or task. After a minute, two groups join together to double the numbers. The activity is repeated; they have to reach a common response. Groups join again and again, until finally two large groups join together and the session leader creates a single response for the whole group.

Jigsaw

The class is divided into groups. Each group must have the same number of children, as there are groups, i.e. if there are five groups, then each group has five children and they are numbered respectively. All the number ones then form a new group, as do the number twos and three and so on. Each new group of single numbers is given a question or scenario to discuss for a limited time period, at the end of which they return to their original groupings and report back on the discussions.

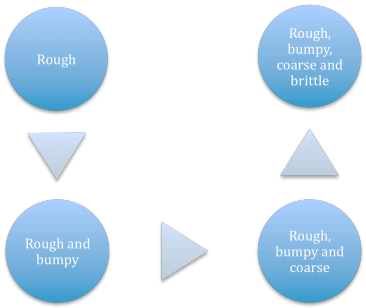
This is an effective way of developing children's listening and memory skills, and at the same time encouraging them to make connections between similar discussions.



"[Critical skills] has changed the way I deliver sessions totally. I am listening more and thinking ahead instead of being in the moment all of the time…"

- Museum Learning Officer

Tools for handling



Building up

Whilst passing an object around the group, each child thinks of one word that describes it. When the object is passed on the next child repeats the first word and then adds a second, and so on. The description builds as the object is passed around the table with children actively listening to each other. It works best if the exercise is strictly time-limited, although children can pass if they cannot think of a word.

Team roles

An effective tool to use with all year groups, although the younger year groups may need more support for it to be effective (three of the most commonly used team roles are listed here). Each child is given a role and prompts if necessary, such as Team Representative, Resource Manager or Recorder. It is their responsibility to carry out their role and contribute to the smooth running of the group. You could have two children carrying out the same role and use sticky labels to define the roles.

Team Representative thinks about what needs saying and reports at the end of the activity: Who will you be reporting to? What do you have to say? How long will you have to speak?

Resources Manager thinks about resources: Have you got the materials the group will need? Have you got the tools the team will need? Is your work area tidy and useable?

Recorder thinks about capturing the discussions: What information do you need to record? Is it recorded clearly and accurately? Who are you recording the information for? Has everyone had a say?

Tools for decision-making

Sweep

Any child can initiate a sweep of ideas. Going round the group clockwise, each child gives a response to a questions or problem. It is way of enabling all children to contributed equally and can be used to collate ideas, resolve disagreements or create solutions.

Whip

Similar to sweep but each person only says one word or phrase. It is really effective at eliciting quick responses from everyone in the group, or to get a consensus. It is a little more involved than simply voting, where children tend to follow their friends.

Thumb Tool/Fist of Five

Asking for a quick show of thumbs is a simple and effective way of seeing who understands: thumbs up = yes; thumbs down = no, or thumbs to the side = unsure.

Using a scale of 0 (negative response) to 5 (positive) on one hand is a slightly more advanced version of thumbs.

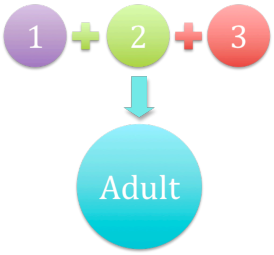
Tools for independence

Use of Group Representative

Make one child in each group the Group Representative. If the group need further clarification on a task, assistance or resources then the only person that can move around the classroom to seek advice from the session leader is the Group Representative. Some session leaders print off special labels for these children.

Magpie list

By providing each group with a stack of post-it notes, they can note down their thoughts, ideas and questions whilst engaged in an activity, as opposed to sharing these with everyone in the room and disturbing learning. This can reduce noise level and is also a useful way of drawing everyone together at the end, sharing similar questions or comments from the collection (hence 'Magpie') of notes.



Ask three then me

A simple, quick way of reducing the queue of children waiting to speak to the session leader is to encourage asking three people before seeking guidance from a session leader. It reduces dependence on adults for answers to simple questions. A child is still encouraged to ask an adult if a query has not been answered.

Tools for evaluation/summing up

0-10 Line Up

With one end of the room labelled as '0 = no', the opposite as '10 = yes', ask the children to place themselves on the line in response to a statement, such as: *"I know more about volcanoes than I did at the start of the session", or "I would be able to explain to my family why there could not be a volcano in Bristol City Centre".*

This can be done at the beginning and end of a session comparing changes in position. This demonstrates to the children how much their knowledge, skills or confidence have developed.

Huddle

Children quickly get into small huddles, heads close and voices low, to discuss an answer or response. Particularly good if you want to introduce an element of assessment into a session, such as a quiz. It adds energy and excitement quickly, but in a controlled way.

Spying

Someone is nominated as 'spy' - a child, adult or the session leader. This is a fun way of collecting anecdotes, quotes and snapshots of activity during a session. Armed with a digital camera or notepad, the spy circulates the room collecting evidence, such as effective group work, good use of technical language or initiative, for sharing in plenary.

Images taken during the session could be uploaded and shared straight away to talk about the good things the spy has seen. Class teachers often like doing this as it gives them a chance to observe their children.

"The children in my class are a lot more independent now and less dependent on me. I often hear them saying to each other: 'have you asked three first?' It has given them a language to be independent."

- Year Five Teacher

Top Tips

We have summarised the key messages featured throughout Part B as a quick reference guide for outreach practitioners.

- It is… important to stress that public engagement should focus on learning outcomes and not lists of objectives: Page 13
- [A child's] ability to understand key concepts and should inform the language and nature of activities that they engage in during sessions: Page 14
- Session leaders should talk for no more than 10 minutes at a time, punctuated with 20 minutes for a physical and practical activity: Page 14
- Children of the later phase, have relatively matured brains and can listen and pay attention for up to half an hour in a very good learning environment: Page 14
- Session leaders could use the Learning Cycle (as seen on page 15 and in appendix) to plan out the different types of learning opportunities that may feature and it is considered good practice to include all aspects of the cycle where possible: Page 14
- [Activities] start with the session leader explaining why they have come to the school and what type of things the learners may be asked to do. The activities increase in duration and participation as the children become more familiar with the content, slowly draw to a close with a plenary or verbal summary: Page 15
- When using behaviour techniques, it may be helpful to ask the teacher what strategies they use to bring the children together: Page 15
- It is highly recommended that session leaders use questions as titles as well as throughout sessions, ensuring that they take into consideration a child's developing awareness of the world (page six): Page 16
- 'How' and 'Why' questions should be saved for the later phase, as they require more complex answers that usually involve explaining a concept or use of technical language. This is very challenging for a younger child: Page 16
- To get children thinking… ask them to come up with questions at the start of a session that they would like answered by the end. This is a valuable exercise to do with a group you do not know, as it will indicate if they are particularly inquisitive and the children will determine how much prior knowledge they have to inform a session: Page 16
- The critical skill toolbox can really help to promote enquiry-based learning in public engagement sessions: Page 17
- The seminar materials: presentations, notes, Pick and Mix exemplification and additional materials used may be viewed on the HE STEM website and are available for you to use and adapt to assist public engagement I your setting. (http://www.hestem-sw.org.uk/widening-participation/wp-projects/?p=16&pp=Enhancing+Public+Engagement+-+A+Guide)

Part Three:

Leading the way with Earth Sciences – A Case Study

A short account of how the School of Earth Sciences at the University of Bristol, is building capacity to lead effective public engagement activities

The School of Earth Sciences has always involved itself with public engagement. However, if has often been ad hoc and without any prior training or strategic purpose.

> 'The seminars have totally changed my perception of primary school learning'
>
> *- PhD seminar participant*
> *University of Bristol*

Background

The Bristol Dinosaur Project (www.thebristoldinosaurproject.org.uk) has implemented a more structured workshop offer and in turn provided training opportunities for those involved in delivery. As well as paleontology, the department deals with earthquakes and volcanoes and was identified as having distinct gaps in public engagement activities in these two areas subject fields. Many of the school's volunteers in the department didn't want to assist with dinosaur workshops, and so by developing this project, the school has been able to provide further opportunities for post-graduates. For those studying volcanoes or earthquakes to get involved with public engagement activities has provided a renewed purpose, especially in helping to deliver activities in schools around these two subjects. The aim of the project was to both widen and improve the effectiveness of public engagement participation and outreach activities undertaken by STEM academics in the School of Earth Sciences at the University of Bristol. It specially targeted undergraduates, Masters and PhD students to develop public engagement skills by providing activities, events and high profile work on volcanoes and earthquakes through accessible and interactive learning activities to schools and families.

This was achieved through collaborative working with the School of Earth Sciences' Learning Officer and a specialist learning consultant to produce written guidance, supplemented by seminars, for its target audience, with outcomes that included creating a range of materials for workshops in schools sustainable beyond the project duration.

Seminar One focused on specific principles and movements within primary education, such as the integrated enquiry-led learning, and highlighted key thinking (such as 'age = concentration' and 'teaching another = 90% increased retention'). Sessions ended with Q&A from participants. Three main issues from participants emerged:

1. Variety of session structures, not always sticking to a PowerPoint introduction for example and ensuring that a plenary featured as a means of consolidating the learning, not leaving it too open (followed up in seminar two)
2. Enhanced expectations of the primary classroom, i.e. behaviour, age-appropriate language and types of activities.
3. The need for flexibility and adaptability in both content and activity depending on the level and ability for the group (followed up in seminar two).

Seminar Two focused on possible session structures and content. Participants were encouraged to work in groups, in line with their specialism, and to create a variety of activities that could be packaged in a different ways according to length or depth. The 'Pick and Mix' approach enables outreach leaders to respond to needs of individual schools without worrying about changing content and resources of each activity.

The seminar materials: presentations, notes, Pick and Mix exemplification and additional materials used may be viewed on the HE STEM website and are available for you to use and adapt to assist public engagement I your setting.
(http://www.hestem-sw.org.uk/widening-participation/wp-projects/?p=16&pp=Enhancing+Public+Engagement+-+A+Guide)

What were the barriers to success?

Alongside the normal barriers of timing, research workload and university exam timetables, the most prominent barrier was indifference towards the primary phase amongst attendees, as previous outreach and public engagement was focused on secondary and Further Education. Although attendance at seminars was healthy (approximately 25 attended), it was notably difficult for some participants to let personal experiences of primary school cloud their perceptions of what was possible. This was mitigated in part by the style of Seminar One - a lecture - so that participants were encouraged to simply listen, absorb and reflect on experiences inwardly, instead of spending a disproportionate amount of time discussing their experiences. It was also considered to be more effective to deliver material in a form that the participants were more familiar with (Seminar Two being more centered on group work and discussion). This avoided stretching participants too far beyond their comfort zone. Finally, the exemplary material used in the seminars was very much focused on the School of Earth Sciences, such as the adjusted presentations for different-aged groups. The correlation between the materials and primary phase pedagogy used in the seminars, exemplified the possibilities for participants; they were able to use it as a benchmark.

What are the outcomes and impact?

Prior to the project most participants had a limited knowledge of the primary phase and the methods and practices used within it. Some of the materials previously produced, although good, were text rich and concentrated on imparting knowledge. Throughout the seminars and in subsequent communications, participants report that reducing the number of activities yet making them more experiential (building on and focusing on specific aspects of their specialisms) would be more purposeful (and more fun!). A few participants even reported an increase in confidence with delivering activities, so much so, that they are considering applying to become trainee teachers.

Most participants showed increased interest, understanding and awareness of the relevance and importance of Earth Sciences within the lives of very young learners and understood that by captivating learners at an early age, they may be empowering them to go to university, study the sciences and use these in future employment.

During the second seminar, when groups were planning and devising a variety of activities, it came to light that one academic had a huge amount of experience of the primary phase and started to advise others on activities that have/would work. Sustainability in action!

A significant positive outcome of both seminars was the personal and professional reflection of the participants, specifically on current public engagement activity within the school and the extent to which it reflects present practice and thinking in primary schools. Many actively discussed and debated the purpose of sharing specific information in specific ways with children, and within a short period of time, adjusted their thinking accordingly.

What could we have done better?

Although unavoidable within the timeframe of the funding agreement, the time of year was challenging in some

ways, although helpful in others. Seminars fell in mid-May, during end-of-year examinations and many staff and students at the University were engaged in them in some form. However, lecture hall availability was improved due to the absence of lectures, and because of this, perhaps more academics may have attended than if it were held at another point of the year. In order to maximise the engagement of academics, future seminars could feature three times per year, with smaller practical question and answer sessions after these. The Q&A sessions would enable smaller groups of dedicated participants to review their activities and plans with a more experienced session leader.

The impact of the seminars may have been improved if there were supplementary materials available for participants to digest at their own leisure, such as: exemplar public engagement session models; annotated resources and video resources of both general primary classroom activities and current (successful) public engagement sessions from other areas such as the Bristol Dinosaur Project. Using a Virtual Learning Environment, which most students and staff are familiar with, may have captured the interest of more people.

Key learning

1. The collaboration between a primary specialist and a HE specialist was essential. Neither party could have accurately delivered the brief independently.
2. The seminars were very successful at providing opportunities for academics to discuss pedagogy, practice and possible ideas.
3. Structures for public engagement sessions were vitally important as they provided the primary pedagogic principles and helped academics shift to fitting specialisms into the primary mould.
4. Exemplar materials, such as amended PowerPoints which exemplified specific aspects of the primary pedagogy, with specific reference to the teaching tools, were very helpful and could be taken further to include online video and children's work.
5. The very nature of public engagement with schools is too broad to cover effectively, potentially involving seven different phases of learning. By focusing on two phases (Key Stage One and Key Stage Two, with reference to the Early Years and Foundation Stage) and specific pedagogy and issues within them made discussions and dialogue much more focused and purposeful.

Top Tips

Should you wish to run a similar project/seminars in your own institution, it is recommended you consider the following:

- Provide this guide to participants prior to the seminars so that they are familiar with the aims and purpose.
- Repeat the seminar, several times in one day. This means that people only have to remember one date yet can turn up when it suits their daily timetable.
- Make links with a practicing teacher and co-deliver the seminars. Part of the power and success of seminars was the ability to draw on anecdotes and experience.
- Where possible hold a seminars a discussion, rather than a lecture. The more informal sessions encouraged participants to reflect more and ask questions.

Part Four:

The future of STEM Public Engagement

A summary of our thinking for Higher Education Institutions with regard to developing Public Engagement activities

This guidance suggest to those in HE STEM public engagement to consider the following recommendations and to become fluent in the following issues to make sustainable and positive change to the STEM workforce and the teaching and learning of graduates moving towards it.

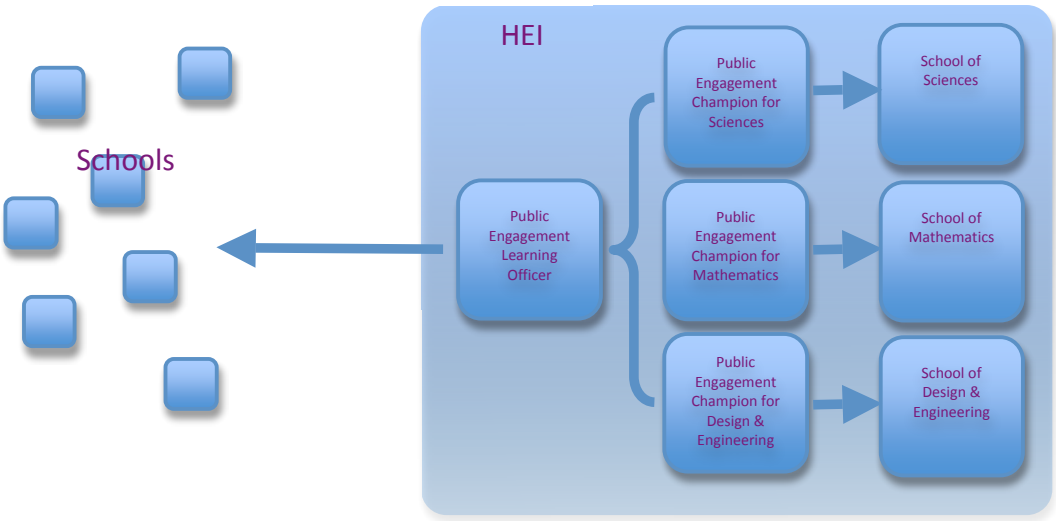
The recommendations below are suggestions based on the literature review (Part A), the collective knowledge of primary pedagogies as an active learning practitioner and consultant (Part B), as well as the case study experience in Part C.
All the suggestions are considered possible within an institution and therefore readily addressed

Recommendations

Higher Education Institutions, public and business community:

What role could each school within a university have in creating a network of in-house Public Engagement Champions?

Younger children need to get 'switched on' to STEM subjects at a much earlier age, where they are beginning to see the links between their learning and the real world. Getting pupils to appreciate the excitement and relevance of their learning is the best way to motivate future interest. Trying to engage a disinterested 14 year old is too late. Creating a champion per school within a HEI would create sustainability beyond that of a motivated individual. Activities offered, and therefore materials, resources and volunteers, could be maximised if STEM disciplines worked as a united body.



To what extent are schools from all phases, not just secondary, aware of opportunities for working with initiatives† that appear to be making a great impact on teaching and learning?

Individual HEIs should seek out Local (Education) Authority Advanced Skills Teachers to advise and develop partnerships with both primary and secondary schools. Advanced Skills Teachers are currently nationally funded specialists across primary and secondary and, if not run, then have access to, networks of schools, initiatives and contacts across an authority. On every local authority website there will be a publically available list of Advanced Skills Teachers. If lists are not available then there should be a list of advisors in the authority, one of which will line manage the ASTs.

† For example: STEMNET, employing STEM Ambassadors, the National STEM Centre, Science Learning Centres and businesses that already have a strong commitment to work placements and apprenticeships.

In what ways are national learning agendas, such as skills-driven or enquiry-led learning, relevant to a local context?

HEIs should seek the guidance and expertise of local authority advisors or external, independent consultants to assist in the localisation of public engagement offers. It makes more sense to maximise the local movement and opportunities available, rather than provide what the HEI believes to be appropriate, but that may have a poor uptake.

In what ways are STEM Ambassadors recruited? Are businesses targeted as a whole, or is there a role for recruitment through the network of parents and careers, whose children attend school?

All schools know the occupations of family members and could play a role in the promotion of STEM Ambassadors. If parents see and hear the impact that HE STEM public engagement activities have on their children, they may be more motivated to take this engagement further. In addition it is imperative that HEIs strengthen the links with local STEMNET contract holders.

How do HEIs promote public engagement with schools?

If an HEI is fortunate enough to have a Public Engagement Centre, to what extent are they familiar with learning prior to Key Stage 3? It is essential that within the PE Centre at least, and preferably within departments, there is a PE Learning Officer whose primary role is to connect with, and translate, the work of the department with local schools from Early Years through to A-Level. This would be different to that of a PE Champion, whose role is more inward focused on the staff and students within the HEI, compared to a Learning Officer who would be outward facing.

Schools and teachers:

To what extent do teachers of all phases, who are less likely to be specialist in STEM, inspired and supported to be able to enthuse students towards becoming enquiring in spirit and practical in process?
It is recommended that the assessment-driven agenda of schools must be balanced in favour of really engaging and challenging teaching and learning, which will bring about its own return in results. Where possible, non-specialist teachers need to collaborate with specialist teachers to enable integration of teaching and learning across STEM subject areas.

Appendix

The Learning Cycle
(Integrated Planning Process ©)

Class/yr group:
Date:

WOW!

(Engaging **events, guided by an adult initially; a supported experience)**

Learners could:
Listen; discuss; engage in an issue; use a text or image to stimulate discussion; watch film clip; piece of music; go on a visit, meet real/imaginary visitor.

When are we going to introduce the challenge?

Learners could:
Demonstrate their understanding by writing recounts, plays scripts, making a TV commercial, organising an event, poetry, dance, music, or making models...

The Challenge

(Proving learning; answering the question by teacher stepping back support and empowering others to excel)

Immersion

(Developing **empathy**, speaking & listening activities; opportunity for learners to ask questions – pupil voice)

Enquiry question:

Home learning question and task:

Have-a-go

(Responding to learning by showing an understanding; having a go, making mistakes and developing skills)

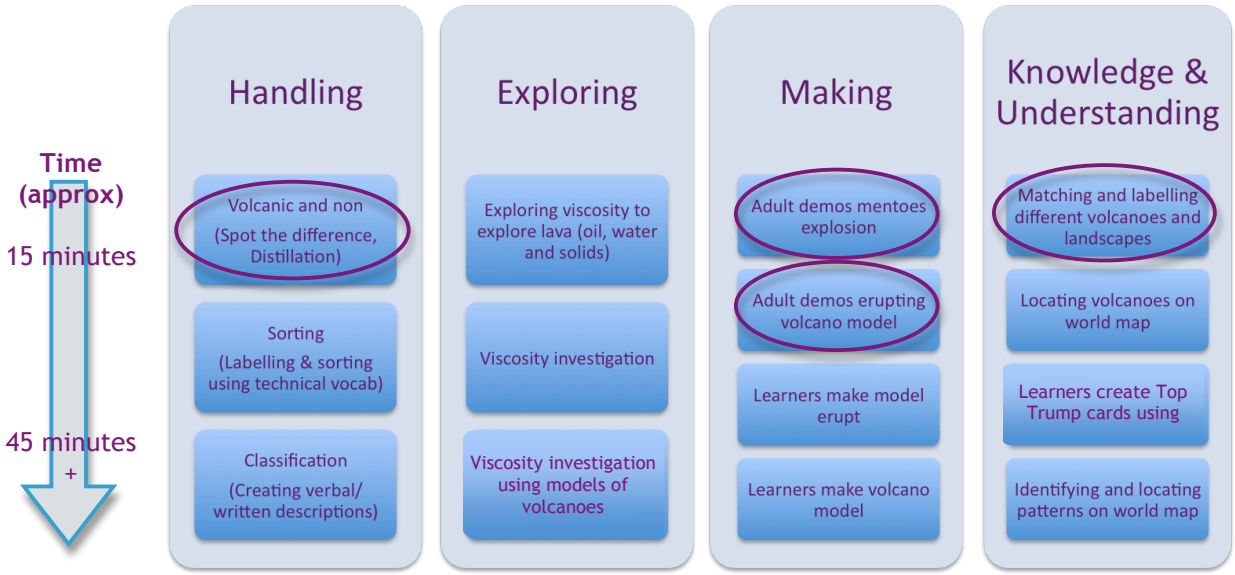
Learners could:
Create a tableau; hot seat; note down ideas; words or sentences on sugar paper; collect different elements of the experience to create toolbox or learning wall.

How and where are they going to record their journey?

Learners could:
Produce draft journal entries from different perspectives; give verbal presentations; use different instruments as representations, or create mini cardboard models.

Pick and Mix

Discussions with a setting before a visit will determine how an offer could complement or enhance learning. A class teacher may be interested in a certain type of activity such as handling or making, or a length of time suitable for their learners.



The matrix above offers flexibility, suits a range of age groups and style of learners from the visual to the kinaesthetic.

Each column is a different type of activity with most being many practical and 'hands on' - the most effective mode of learning (as seen in the Learning Pyramid, page 9, Enhancing Public Engagement). The setting should be able to guide you by choosing the style of activity preferred.

Activities within each column increase in length and complexity with the shortest and simplest at the top, the most complex at the bottom. 'Complex' refers to the level of technical language, explanation, resourcing or length of time required to complete the activity. The more complex activities could be started in school with the guidance of the expert session leaders, and then extended and completed post visit.

Diamond or carousel?

There are two suggested models of sessions: diamond and carousel. A diamond is when everyone engages in the same activity with the session leader 'delivering' (further information on this structure can be found on page 7, Enhancing Public Engagement). In contrast, a carousel enables the session leader to facilitate learners rotating between several, equally timed activities with all learners experiencing all by the end of a session. This is particularly effective if learners are very excitable or active.

The standard offer

Many schools will simply accept what is on offer as the providers are seen to be the experts. It is up to the session leader to select the most appropriate activities suitable for the age and prior subject knowledge of the children. For example, activities circled above could be used in a one-hour session for the middle phase (year 3, aged 7 to 8 years old).

The bespoke offer

Some schools will have a specific learning outcome or purpose in mind. Hopefully, they will share this with the session leader. However it is advisable to ask how the proposed workshop fits into the wider curriculum. This will enable session leaders to pick and choose appropriate activities to form a package. Time and resources will play a major factor in choices; the recommendation is always to overestimate how long an activity will take. (Top tip)

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