urban science

Framework for Science in the Urban Environment

Working draft June 2018

Urban Science – Integrated Learning for Smart Cities

Over two-thirds of the European population live in cities. Enabling those cities to deliver services sustainably while keeping their citizens safe, healthy, prosperous and well-informed is amongst the most important challenges in this century. The Urban Science European project is an education response to this, to improve the teaching of scientific inquiry and investigation so that pupils develop the competences to actively contribute to creating healthy cities, gain scientific skills to enter the world of work, and meet the demand for the urban scientists of the future. Urban Science works through outdoor inquiry-based learning where urban areas become living-laboratories that help pupils explore how science can create healthier and sustainable places to live. It is solutions based; placing a strong emphasis on creativity and problem solving to ensure scientific understanding can be applied in a meaningful context. The project draws on several influences in inquiry-based learning and an understanding of how the natural world provides a systems model for sustainability. Critical to the success of the project is weaving together the needs of curriculum in the partner countries, teacher competences and learner profiles. This article provides an exploration of the development of the learning framework the project is developing, how this builds on recent work in the field, and adds value to the increasing call for and need to educate pupils in scientific literacy for a sustainable future.

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It is a partnership between:

Visit urbanscience.eu for more details.

Contents

1. Introduction

The goal of Urban Science is to improve the teaching of scientific inquiry and investigation so that pupils develop the competences to actively contribute to creating sustainable cities, gain scientific skills for employment, and are more motivated to study science.

This framework document lays out the principles and thinking behind Urban Science. It is intended as both a practical document for teachers and educators to develop their own learning modules, and to understand how ready-made resources have been created. It also provides a theoretical background to the development of Urban Science learning; links and references are provided throughout the document to enrich the knowledge of those who wish to delve deeper.

The framework is an evolving process. Urban Science learning modules will be developed based on the framework, trialled and reviewed. Further iterations of this document will follow as we become more established in our approach based on practical success in classrooms across Europe.

2. Overarching Principles

Over two-thirds of the European population live in cities. Enabling those cities to deliver services sustainably while keeping their citizens safe, healthy, prosperous and well-informed is amongst the most important challenges in this century. The Urban Science European project is an education response.

Urban Science works through outdoor inquiry-based learning where urban areas become living-laboratories that help pupils explore how science can create healthier and sustainable places to live. It is solutions based; placing a strong emphasis on creativity and problem solving to ensure scientific understanding can be applied in a meaningful context. The project draws on several influences in inquiry-based learning and an understanding of how the natural world provides a systems model for sustainability. Critical to the success of the project is weaving together the needs of curriculum in the partner countries, teacher competences and learner profiles.

Urban Science is underpinned by an understanding that:

- Europeans are becoming more urban.
- Cities account for the majority of environmental impacts directly or indirectly.
- Changes within cities can have greater traction.
- There is an urgent need for cities to re-invent themselves to be future fit.
- Cities are living systems which are complex and dynamic.
- Without supportive natural environments, we will not be able to create sustainable cities.

Urban Science therefore:

- Asks how science can contribute towards sustainable cities.
- Proposes that IBSE is the most suitable approach to deliver science.
- Uses real world learning to motivate pupil engagement.
- Explores how issues are connected holistically.
- Aligns science with values and future-thinking to create sustainability.
- Raises pupils' positive views on the role of science towards a sustainable future.

3. Competences

Contributing to creating sustainable cities requires pupils to develop a broad range of competences for inquiry-based science and sustainability. Below we list two sets of competencies and highlight those critical to Urban Science. The lists should not be viewed as separate; rather they are seen as complementary competences developed through each other: IBSE provides the approach and sustainability the context.

3.1. IBSE Competences

The list provides a comprehensive list of IBSE competences. These are for guidance. Each Learning Module will select only the competences appropriate for that Learning Module. However, over an annual cycle or several Learning Modules, all competences should be addressed.

	IBSE Competences
1. Develop knowledge and understanding of key Urban Science issues	1.a. State observable features
	1.b. State or use a classification system
	1.c. State a relationship between variables
	1.d. Show understanding of scientific theory
2. Learn how to	2.a. Identify equipment
	2.b. Use equipment
	2.c. Describe a standard procedure
	2.d. Carry out a standard procedure
3. Develop an understanding of scientific Inquiry	3.a. Propose a question
	3.b. Plan a strategy
	3.c. Evaluate risk
	3.d. Collect relevant data

	3.e. Present data effectively
	3.f. Process data
	3.g. Interpret data
	3.h. State a conclusion
	3.i. Evaluate a conclusion

3.2. Sustainability Competences

Sustainability competences need to be referenced through a deeper understanding of the sustainability challenges facing Europe; it is not the purpose of this document to assess this and further information can be found here[1]. Broadly speaking we can consider those challenges as:

First Order: we know what the issues are, we know how to address them; the role of education is to inform society what it needs to do. An example is recycling as a solution to the issue of waste. The goals and paradigm of society remain unchanged[2].

Second Order: we know what the issues are; addressing the issues requires radical change in how we approach solutions and the role of education becomes developing competences to explore and implement new solutions. An example is the circular economy which views 'waste' as 'food' for new processes. The goals and paradigm of society remain unchanged.

Third Order: in this level the goals and paradigms of society itself are questioned; new forms or organising and being emerge; solutions become contextualised in a whole new way. The role of learning seen as constant experimentation, feedback, revision and iteration as learners tackle complex and inter-related issues.

Urban Science is sited as a progression from first order to second order learning and change; empowering pupils to reimagine cities in their future and teachers to grasp wider transformative learning opportunities. Sustainability competences need to be viewed in this context; competences that are characterized by the unique role they play in addressing the sustainability challenges and opportunities that are before humanity.

Sustainability Competence	**Description**
1. The ability to understand systems and apply systems thinking (inputs, outputs, connections, loops, feedback)[3].	1.a. Able to connect different elements within an urban environment; 1.b. Seeing how they relate to each other; 1.c. Recognising that all actions are part of a system; and 1.d. Often have multiple consequences positive or negative.
2. An understanding of how natural systems function, ecological limits and resource constraints[4].	2.a. Understanding how natural systems work within limits and use a range of strategies to adapt, optimise and flourish; 2.b. To understand how human activity that exceeds ecological limits or capacity has negative effects; and

[1] Learning for a Change
[2] For more see http://donellameadows.org/archives/leverage-points-places-to-intervene-in-a-system/
[3] See State of Washington Science Standards for more on progression in system competences.
[4] See The Donut of Social and Planetary Boundaries and Planetary Boundaries.

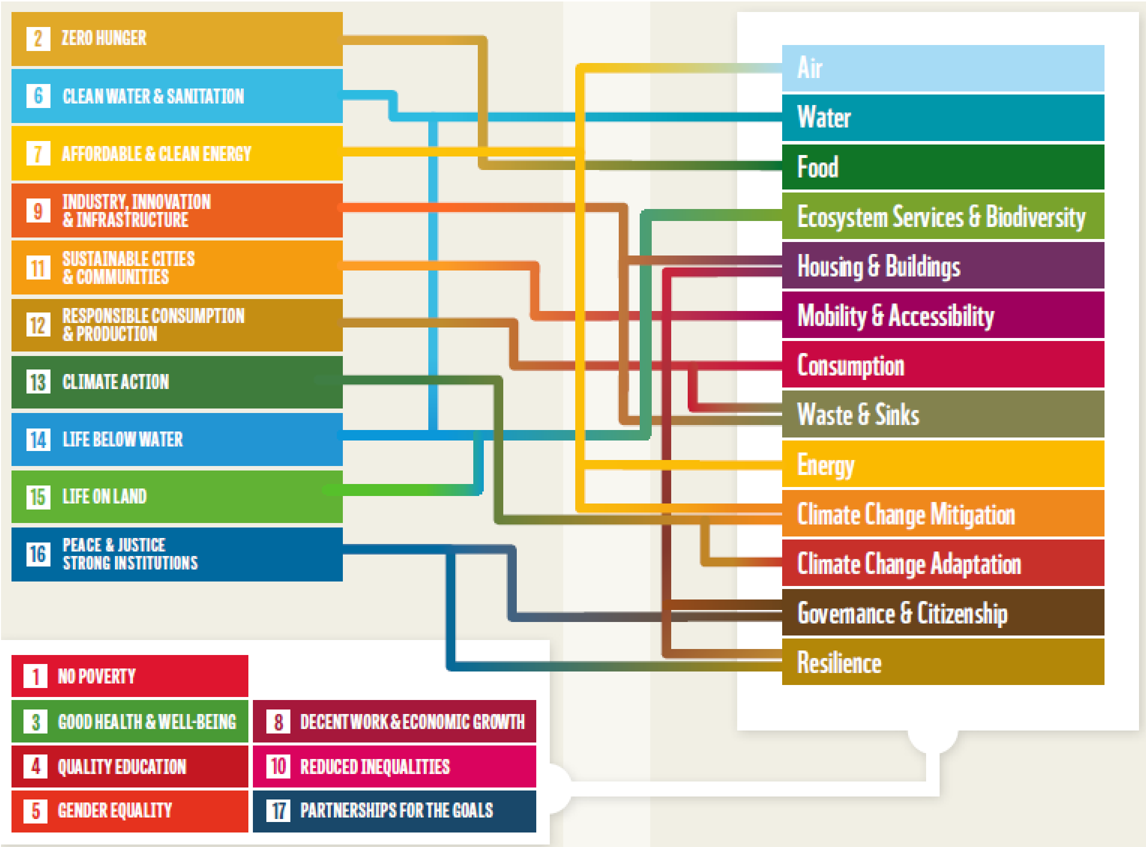
	2.c. Sustainable systems balance resource use within a fixed carrying capacity.
3. The ability to think in time - to forecast, to think ahead, and to plan.	3.a. Develop ideas for alternative futures 3.b. Understand alternative futures 3.c. Evaluate alternative futures; and 3.d. Able to predict the consequences of actions today on future choices and their ability to act.
4. The ability to think critically about value issues[5].	4.a. Identify behaviours and values that reinforce a sustainable future; and 4.b. Able to apply a values perspective to decision-making; integrating scientific knowledge with personal and societal values in making choices.
5. The ability to separate number, quantity, quality, and value.	5.a. Being able to distinguish between actions which improve or quality of life versus quantitative changes in material standards.
6. The capacity to move from awareness to knowledge to action.	6.a. Able to take responsibility to develop and implement plans; and 6.b. Evaluate their success.
7. The capacity to develop an aesthetic and compassionate response to the environment	7.a. Having a sense of connection beyond self, 7.b. See the needs of others; and 7.c. Demonstrate compassion and sympathy for others and the natural world.
8. The capacity to use these processes: knowing, inquiring, acting, judging, imagining, connecting, valuing, and choosing.	8.a. Being able to integrate a range of technical and emotional capacities; and 8.b. Know which capacities to apply to a given situation.

Tracking the progressive development of competences is important and developed in 'Methods and Pedagogy' section below.

4. Content for Urban Science

The Sustainable Development Goals[6] are a powerful mandate driving sustainability. WWF Urban Solutions for One Planet Living[7] maps these against key themes for a sustainable city (see below), providing Urban Science with examples of linkages between potential Urban Science themes and the SDGs. Descriptions of each theme are provided in annex 1.

[5] See The Common Cause Handbook.
[6] UN Sustainable Development Goals
[7] WWF Urban Solutions



This can provide an overall framework for Urban Science content. Each partner country has their own curriculum content requirements which are mapped against the themes (see table below). A coherent whole is developed so that individual content elements link to broader themes. This 'framework' supports a holistic approach to viewing sustainable cities; additional themes can be added and new linkages made.

Urban Theme	**SDG**	**National curriculum content**
Air	7	*Completed by each partner* *Add examples here…*
Water	6, 14	
Food	2	
etc		
Apply across all themes	1, 3, 4, 5, 8, 19, 17	

Each Urban Science learning module are based on one or more urban themes linked with relevant curriculum content. All link with a wider city perspective ensuring the whole system is not lost in the 'parts'. Urban Science Challenges drive the learning for each module.

The content of the Urban Science learning modules is also driven by Urban Science Challenges; situations and/or scenarios to invoke curiosity and questioning as starting points to deeper exploration. The nature of the Urban Science Challenges is still open to discussion; they can be specific to a theme or cover a range of themes; they can be the focus for a whole classroom investigation or for smaller groups. As with the whole framework approach flexibility and adaptability is key. Suggestions include:

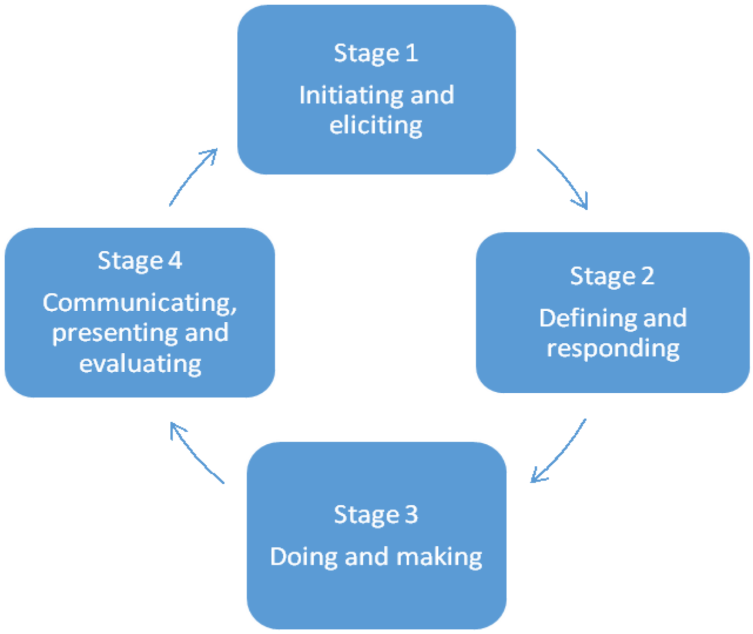
School Challenges	Challenge Background	Key Theme
Can we take back our streets?	The average car is parked 92% of the time, 31% of food is wasted along the value chain, and the average office is used only 35-50% of the time, even during office hours. How do these link and what can be done to reduce impact and produce positive benefits?	Food, Waste & Sinks, Climate Mitigation, Housing & Buildings
Can we have a zero carbon future?	Urban areas are major contributors to greenhouse emissions (60-80% on a global scale); 90% of urban areas are coastal. What are the major contributors and how can systems be redesigned to reduce emissions?	Climate Mitigation, Climate Adaptation
Can we take back our streets?	Approximately 80% of urban areas have air pollution levels that exceed World Health Organisation limits. How can we reduce air pollution, increase green spaces and prevent road traffic accidents?	Mobility & Accessibility, Air, Ecosystem Services & Biodiversity
Where will I live?	60% of the buildings that will exist in 2015 are yet to the build. How can we create buildings that adapt and change over time, are carbon neutral and feed their residents?	Food, Waste & Sinks, Housing & Buildings

5. Methods and Pedagogy

5.1. Model

Urban Science is structured on an IBSE circular model, enabling pupils to deepen understanding through progressive engagement. Here we are adopting the model from Enquiring Minds[8] for shared understanding. Other common IBSE models will also fit, and each country will select appropriately.

[8] Enquiring Minds



The Enquiring Minds approach is based on:

1. Stage 1: eliciting the knowledge, interests, ideas and motivation of pupils. The teacher's role is to help pupils draw on their own lives and experiences to discover things that interest them, make them excited, curious and want to ask questions.

2. Stage 2: shaping, defining and focusing an idea or question, and making plans to research it further. The teacher's role is ensuring pupils can advance their inquiries meaningfully; providing frameworks and learning so that pupils can organise their research.

3. Stage 3: pupil's research, design and construct in order to make a contribution in their chosen enquiry, during which pupils engage in a variety of tasks depending on the nature of their enquiry. The teacher's encourage pupils to manage their time, identify clear goals and monitor their progress.

4. Stage 4: pupils communicate, share and present their new knowledge and understanding with others.

We anticipate inquiry-based learning will provide engaging approaches for teachers to adopt pupil-centred learning. The challenge of initiating learning with pupil generated questions moves the teacher from gatekeeper of knowledge to facilitator of learning. Using locally generated content focused on the urban environment makes learning more meaningful and applicable for pupils, thus influencing their motivation to learn. We aim for a move from knowledge being held by authority figures to one where knowledge is dynamic, collaboratively developed and social context matter; teachers and pupils become co-learners.

The inquiry cycle provides a basis for constructing learning. In delivery teachers will decide how detailed support for pupils needs to be. For pupils new to IBSE a teacher-directed approach will be appropriate, and as pupils (and teachers) gather confidence progression is towards teacher-student agreed approaches and finally student-directed inquiries.

A further consideration is how to site the inquiry cycle in the delivered curriculum of the school. At its simplest this could be a single teacher within a single subject. However, to ensure greater breadth and depth of learning moving towards whole department and whole school delivery is recommended. This recognises that science is sited within a range of other disciplines and contextual understanding is critical in using science to plan future sustainability.

5.2. Progression

Tracking competency development is important as pupil's move through the inquiry cycle over a series of rotations. A basic tracking tool is offered in section 6 below. Developing competency assessment tools is the task of Output 4 and not addressed here.

5.3. Pedagogy

Urban Science is not prescriptive about a particular pedagogical approach. Teachers need to decide what is appropriate to their pupils, curriculum and school environment. Approaches should match essential principles for effective inquiry and sustainability learning, through providing a teaching and learning framework that:

1. Understands and builds on the learner's prior experiences
2. Is meaningful and relevant to the learners' own life;
3. Provide first-hand experiences inside and outside the school in a range of settings and contexts;
4. Encourages solutions based on understanding, values and shared responsibility.
5. Allows learners to explore their values and vision for their future.
6. Takes place in a range of contexts spatially and temporally.
7. Involves learning through curriculum subjects, interdisciplinary teaching and the whole school (internal organisation, use of buildings & grounds).
8. Builds capacity for change.
9. Provides opportunities to think, learn and act holistically;
10. Stimulates critical thinking, develops creativity in responding to environmental challenges, and actively encourages participation addressing local environmental issues, relating them to global themes;
11. Cultivates an appreciation for the natural world and understand the dependence of human well-being, healthy societies and economic activity on the natural world;
12. Provides opportunities for feedback thereby allowing for progression to greater understanding

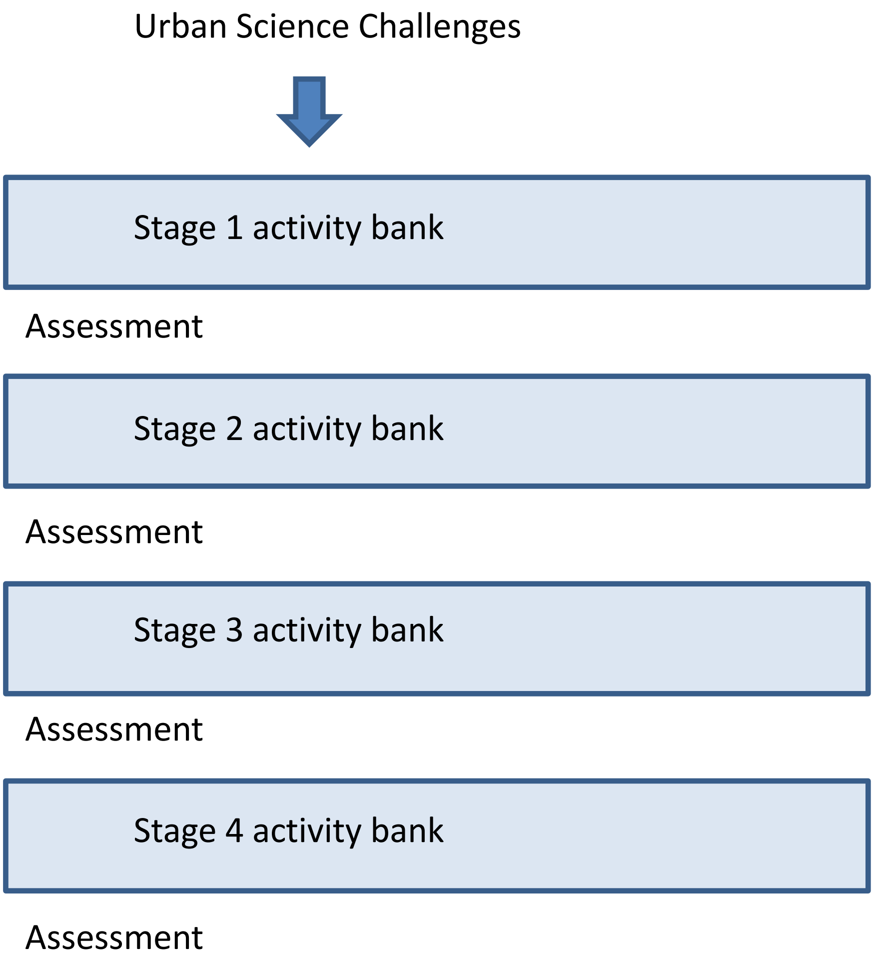
Urban Science strengthens the capacity for pupils to make judgements and choices for a sustainable future. It develops critical reflection, greater awareness and empowerment so that new visions meeting the needs of today and the future can emerge. It informs learners' values through an exploration of the fundamental principles of the way we live our lives now and the impact our lifestyles have on environment and society.

6. Urban Science Planning Tool

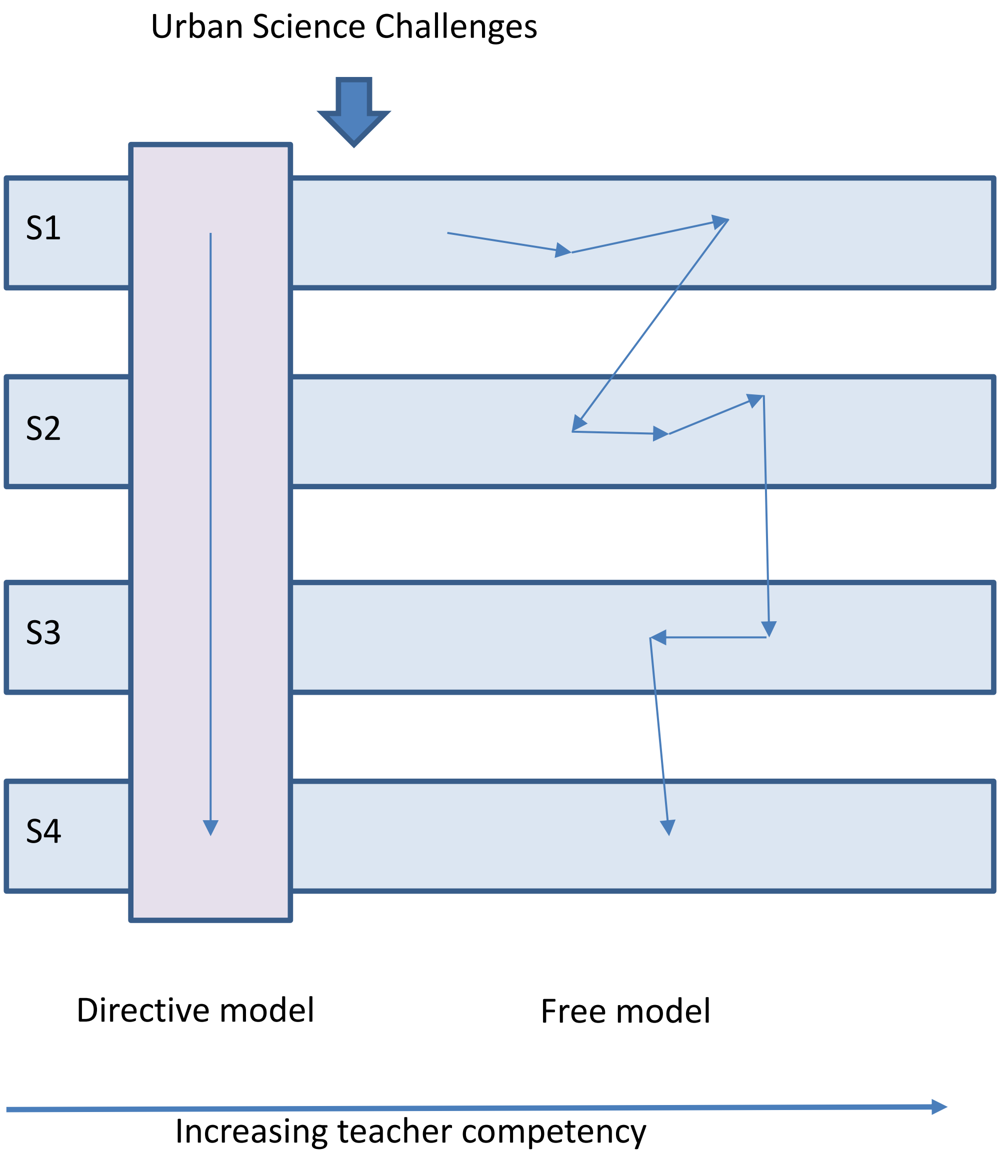
Putting all this above together into an effective planning tool is not simple. The tool offered is an amalgamation of our practical research, experience and theory. It is one approach to develop learning resources that delivers motivating and comprehensive learning. To be effective the tool needs to be used with all the content above in mind. It would be easy to create a very complex, multi-layered tool. Our purpose is to present a tool which is simple and easily applicable for planning and delivery. It is therefore not a ‘complete’ tool, but used in conjunction with the contents above it will offer a comprehensive approach to planning and delivering learning.

6.1. Model

The diagram below offers a model. Activities are developed for each stage, forming a bank or suitcase of activities which can be used flexibly. Assessment tools guide teachers, helping them assess when pupils are ready to move onto the next stage. The 4 stages represent the 4-stage process in the Enquiring Minds model for IBSE.



Pathways through the model are developed to meet the needs of teachers. Each pathway starts with an Urban Science Challenge providing focus and direction. Learning modules can be directive in which case the learning journey through the 4-stages is provided. Or they can be free, in which case teachers select the activities fitting their curriculum/pupils needs. This represents a potential for teachers to move from a directed to a free model depending on their competency with IBSE and Urban Science. In this case, whereas the project will develop 10 directive learning modules, the potential is for hundreds of free learning modules to be created.



6.2. Tracker

The tracker allows teachers and educators to plan their activities to embrace an inquiry learning cycle, and ensure through a range of activities that key IBSE and sustainability competences are achieved. By planning activities through all four stages a complete inquiry cycle is delivered; teachers will need to assess whether to start with a structured, supported or open inquiry Delivery in schools can be fragmented; a key benefit of using the tracker is to ensure that critical competences are delivered over time.

Schools can choose to complete the aspects of Urban Science inquiries over a period of time during their mainstream lessons. Perhaps through a school year, using techniques such as a 'wonder wall' to keep pupils engaged. This takes account of the overfull nature of many European science lessons. In this model tracking and progression is particularly important.

It is also possible to deliver Urban Science topics over a concentrated period of time, for example away from school at a centre or during a 'science week'. We contend that pupils will benefit from a period of 'extended delivery' in mainstream lessons ahead of this. This is an approach followed successfully by the 'Getting Practical' programme[9]. Here students practiced (with feedback) elements of science inquiry over the school year. They were then much better able to successfully carry out a 'full science inquiry' activity unaided at the end of the year.

THEME:									
IBSE Cycle	**Activities**	**IBSE Competences**				**Sustainability Competences**			
Stage 1 – initiating & eliciting									
Stage 2 – defining & responding									
Stage 3 – doing & making									
Stage 4 - communicating									

9 http://www.gettingpractical.org.uk/

Annex 1

From: WWF Urban Solutions for Living Cities

Air
Air quality is a major concern for cities, and for good reason. Air pollution seriously affects human health – with potentially deadly and disabling effects. Air quality is crucial for ecosystems that cities depend on, forests and agriculture, for example. So air pollution presents a major economic threat.

Water
Water holds the biosphere together - it links many environmental issues - pollution, biodiversity, food, energy, climate regulation, and many more. How well we use, manage, waste, or pollute water can determine the sustainability of our environment. Water also connects many issues in urban systems.

Food
The basic need for food is interconnected with other needs and ecosystem services – air, water, waste management, energy, and more. Problems in one system tend to multiply into other areas. But solutions can also be multiplied. For reasons of food safety and health, cities are increasingly engaging in food policies and urban farming.

Ecosystem Services & Biodiversity
Many of cities' basic needs depend on nature's ecosystem services. These in turn are dependent on biodiversity. A wide range of ecosystem services come from the natural spaces in and around cities. They clean the air and water, temper floods, provide water and food, and conserve biodiversity.

Housing & Buildings
Buildings account for almost 40% of carbon dioxide emissions globally, and in bigger cities up to 80%. Many cities have turned to retrofitting buildings as one of the most cost effective ways to make good on promises of greenhouse gas reductions. Most energy-efficiency upgrades pay for themselves through energy savings.

Mobility & Accessibility
Cities need space – and people need to access the city. Mobility and accessibility are tied to a range of other choices that affect ecological footprints and nature conservation. How much land will be used, and how much will be left for nature and agriculture? What energy sources will be used and what kinds of emissions into air, water, and soils?

Consumption
Cities import huge amounts of resources from other places. As cities' footprints spread and join in complex supply chains, urban dwellers may unknowingly cause major environmental damage through their consumption patterns. We are currently consuming nearly 50% more than our planet can sustainably provide.

Waste & Sinks
Given that we have one interconnected planet, we cannot throw stuff away and forget it. It is still there, and can come back in our air, our water, and our food. Expanding the concept of reduce, reuse, recycle should include another 'r' – repair, while sinks must be properly maintained as the part of our environment that can uptake some waste and pollutants.

Energy

Preventing climate change and building resilience in cities require real energy revolutions, shifting towards greater efficiency, and renewable energy use. Cities are leading actors in the transition from fossil fuels to alternative energy sources, as well as "negative-cost" strategies like building retrofits and smart metering.

Climate Change Mitigation
Climate change is one of the largest threats facing people and nature. Climate is basic to our life systems – yet through our actions, humanity is causing the climate to change dangerously. Cities have risen to the challenge and are setting some of the world's most ambitious goals for reducing their impact on the climate.

Climate Change Adaptation
Global climate change carries huge risks – for food security and water security and other life-supporting services. Some impacts will be felt distinctly at the city scale: extreme weather events like heat waves, floods, storms, landslides, and droughts. Urban populations are particularly vulnerable to extreme weather events.

Governance & Citizenship
In cities, everything is closely connected, thus problems tend to multiply, though so too can smart solutions. Cities can exploit positive synergies, or struggle with negative ones. Those that are well-governed and well-designed are usually more sustainable along every dimension. Responsible decisions for people and environment often pay for themselves.

Resilience
The new field of resilience has grown with the approach of catastrophic climate change. Resilience can be defined as the ability of a system to withstand and recover from hazards. The question is how resilient cities will be in the face of climate change and other environmental problems like air pollution or natural disasters.