Toolkit of Innovative Pedagogical Approaches for Teaching with GIS, including the GI Pedagogy Framework and Model

https://www.gi-pedagogy.eu

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"GIS technology will develop into a nervous system for our planet where we, on an ongoing basis, measure and encapsulate knowledge, share it, and respond to issues that people care about."

Jack Dangermond, esri (2017)

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"Every teacher needs to improve, not because they are not good enough, but because they can be even better."

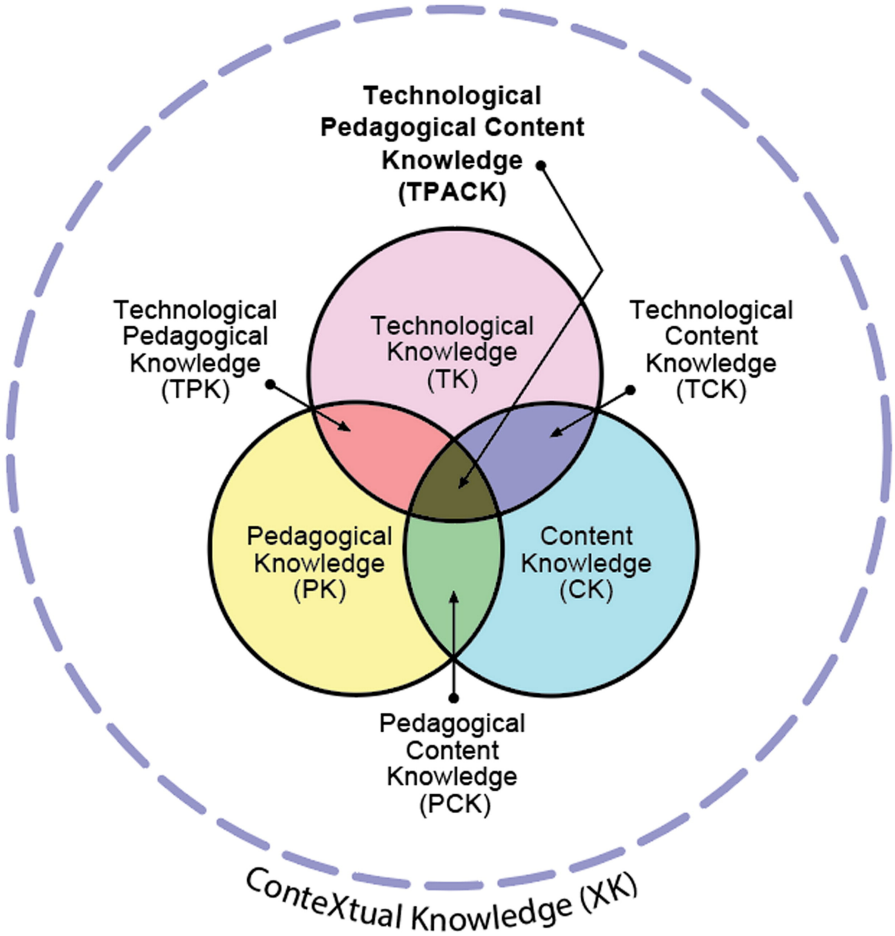
Dylan Wiliam, UCL IoE

GI Pedagogy is an ERASMUS+ funded project (2019-2022). It is a school education project that focuses directly on **innovative pedagogy** specifically applied to national curricula, and aimed at trainee and early career teachers. It was developed as a response to the need to train teachers **how to integrate innovative GI (Geographical Information) Science pedagogy into their lessons**. It seeks to do this by developing teacher training resources and a toolkit document. The project intends to draw together and transform existing available knowledge, materials, concepts, and ideas into the training of **new and early career teachers**, while also offering further possibilities for the professional development of more 'experienced' teachers.

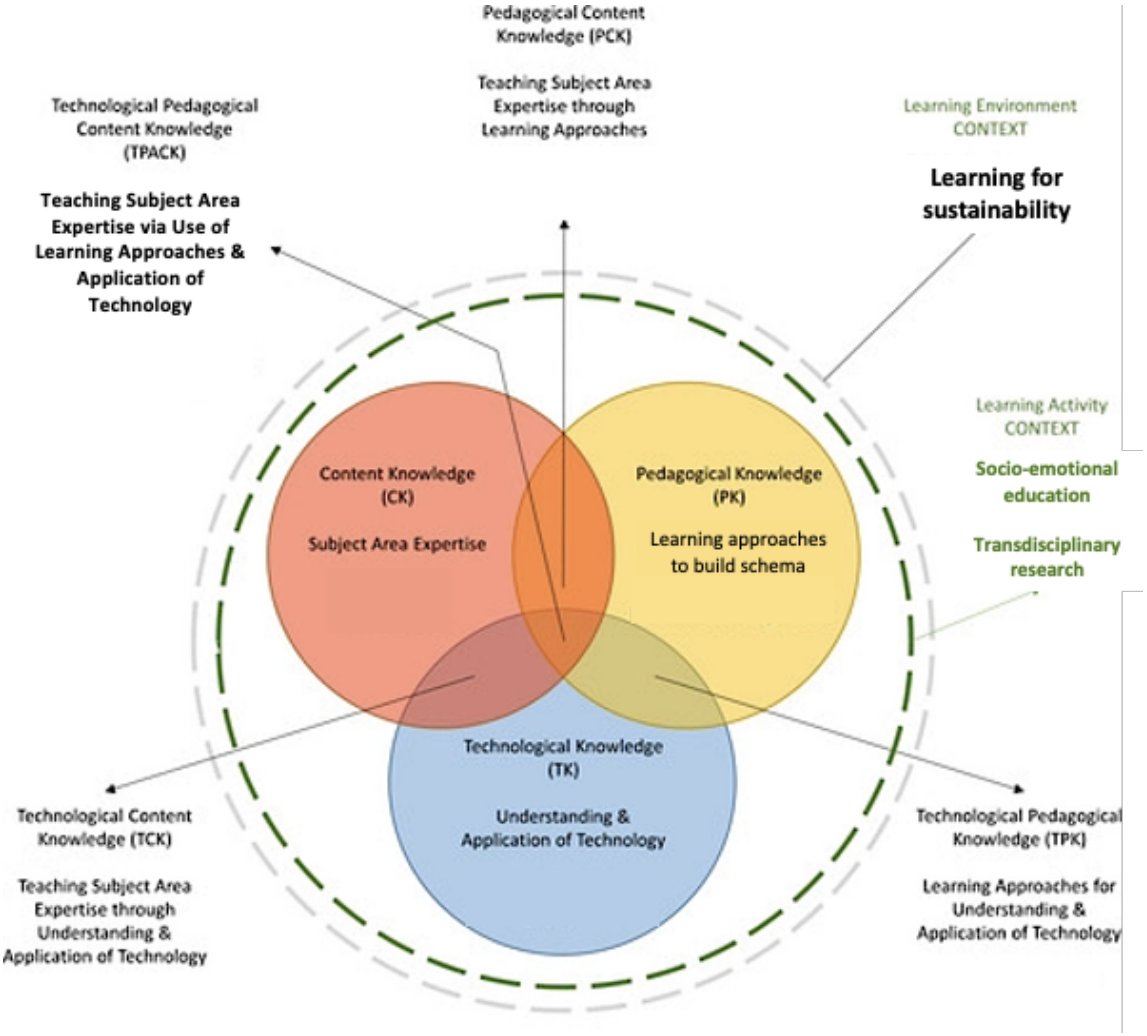
To do this, GI-Pedagogy builds on previous innovative work, including the precursor project: **GI Learner** (which developed a learning line for students to follow to develop their GI competencies), and seeks to incorporate the latest web-based tools and technologies alongside current thinking on cognitive science.
GI-Pedagogy also proposes to take advantage of the exciting and innovative world of **open data** and open science, thus offering access to data sources for schools and connecting the school world with the real world and raising the pupils' awareness of citizenship and data issues and the vital nature of GIS to all of our lives. The project will introduce you to the growing number of easy to use web-based technologies available online, and the increasing access (free of charge) to powerful tools such as ESRI's **ArcGIS Online**, which has the advantage of a well-established programme for schools, allowing them to access the ArcGIS for Organisations version, with its powerful analytical tools.

One principal difference between GI Pedagogy and other GIS-related projects is our particular focus on **pedagogy** (the methods and practice of teaching) and the use of **evidence-based** approaches to the craft of the teacher, following the compilation of a thorough **research**

summary, with recommendations which formed the first output of the project. This involved reviewing and distilling the conclusions from over 100 research papers in this field, including those on cognitive science and GIS. The project's aim is to support teachers, particularly those starting out in their career, to understand **more effective ways to teach with and about GIS**, with a focus on the different variations of **P** in the well-known **TPACK** approach: the **pedagogy.**



Source: Mishra (2019)



Adjusted model for the GI Pedagogy project (based on Rickles, Ellul, & Haklay, 2017, p.16 and Puertas et al, 2021)

Educating for sustainability does not simply require an 'add-on' to existing structures and curricula, but implies a change based on the ability to respond to the current crisis concerning unsustainability and the opportunities for sustainability (Sterling, 2004). This is not the first time that the socio-emotional dimension has been added to an already defined model, e.g. consider what happened to Gardner's 'multiple intelligences', after the linguistic-verbal, musical, logical-mathematical, bodily-kinesthetic, interpersonal, intrapersonal, and naturalistic intelligences were defined (Gardner, 1983). Emotional intelligence (Goleman, 1995) and spiritual intelligence (Gardner, 2006) were added. Affective aspects in teaching practice are important, because much of what the teacher knows and does is connected to their own emotional state and motivation, and this directly influences students' learning. Thus, awareness of the importance of the affective domain in emotions in relation to the content that

is taught changes attitudes and improves teaching effectiveness (Puertas et al, 2021). We aim to improve teachers' connections with GIS.

Table 1. Education for sustainability stages [1].

Teaching Approach	About (Doing Things Better)	Using/with (Doing Better Things)	Investigate and Transform (Seeing Things Differently)
Sustainability	Learning about sustainability	Learning with sustainability	Learning for sustainability in transformative actions
Web GIS	Teaching and learning about Web GIS	Teaching and learning with Web GIS	Investigate and visualize in Web GIS to understand and transform
Responsibility	To the teacher	To the teacher	To the student and teacher

Source: Puertas et al (2021) based on Sterling (2004) and Favier (2013)

One of the outcomes from the project is a suggested model to use when developing activities using GI (geographical information), and to frame your teaching around. **This model is informed by the current thinking in cognitive science** and is designed to be accessible for teachers at all levels of pre-existing competence in the use of GIS so there will be something there for you. At the outset, it is important that you have in mind some end product of your own work with GIS. GIS is essential for all young people to have experience with, it is not just for professionals in business. It improves critical spatial thinking (Kim and Bednarz, 2013; Bearman et al, 2016) and makes it possible to move beyond the TPACK model. This allows for changes in attitudes to territory, and for extension work to deal with sustainability issues and values (Álvarez, 2020; Puertas et al, 2021).

Section 3 provides more information on GIS, and our definition of it, which includes a range of resources such as statistical atlases. In previous projects, we have used the term **'geomedia'** for this sort of information.

There is a particular link here with our research publication (IO1), which can be downloaded from this page:

https://www.gilearner.ugent.be/publications-gi-pedagogy/

The toolkit will explore how to 'unpick' an activity to understand what works and why, and provide some tools for you to use to understand why GIS works.

2 What does this toolkit contain?

This toolkit contains a curated summary of **guidance, suggested tools and pedagogical resources** and case studies to **help early career teachers specifically to gain familiarity with, and confidence in the use of GIS.** It also aims to provide innovative approaches for your own development of pedagogical approaches & scenarios, so that you can help your students become more familiar with the power of GIS in turn. It will take you from an entry-level knowledge of GIS, helping early career teachers move towards more advanced and innovative learning and approaches to teaching with and about GIS in the classroom.

The toolkit aims to provide a path to guide you through the process of working with GIS. It will focus on approaches to learning and teaching which are linked to current pedagogical theory and **cognitive science** and are practical and achievable. The hope is that at the end of your engagement with this toolkit, you will become a better teacher with GIS. **We have aimed to make the structure of our model as straightforward as possible,** but ensure that it is supported by research evidence. This model can be seen in Section 6.

We hope your students will be quickly motivated to learn about, and be excited by the possibilities offered by the technology. The toolkit will also assist you in thinking about your own use of GIS, connecting with the principles of instruction developed by **Barak Rosenshine** to help you consider your own pedagogical intent when using GIS and make it possible to check students' understanding in an innovative way. We have referred to a number of research documents in the development of the toolkit. Frequent use of GIS is an essential part of our approach: GIS use needs to become embedded in your everyday practice if you (and your students) are to gain the **automaticity** which emerges from learning, repetition and practice. This automaticity could be related to early stages of GIS use - we would not expect you to aim to become an expert in all aspects of GIS immediately. We will also provide suggested tools, and a few examples of teacher practice.

We recognise that teachers' pedagogy can be informed by the ten principles outlined by **Barak Rosenshine**, which have been summarised by Tom Sherrington in his book: **'Rosenshine's Principles in Action' (Sherrington, 2019).** We have explored how these principles can

be incorporated into our innovative **model of pedagogy for teaching with GIS** which draws on cognitive science.

This toolkit also connects with some of the other outputs from the GI Pedagogy project: a **MOOC** which will contain a range of worked examples of resources which can be used with a range of GIS tools, which will include ArcGIS Online alongside other web visualisations including Gapminder tools and statistical atlases at different scales. This aims to build confidence in teachers to integrate more GIS, and we recognise that some teachers will begin from a basic level. We hope you will move from this toolkit onto taking part in the MOOC as part of your increased engagement with GIS. The MOOC will develop the use of the model within the classroom, to inform your practice.

The toolkit will explore how to 'unpick' an activity to understand what works and why, and provide some tools for you to use to break down why GIS works. Examples will also be drawn from the GI Learner project, where we worked with students and teachers to develop resources at different levels of competence. Our toolkit covers teaching *about* as well as *with* GIS in order to obtain deep learning.

The pandemic has opened up some new opportunities for remote learning, and these will also be factored into our work.

3 What is the power of GIS?

"GIS technology will develop into a nervous system for our planet where we, on an ongoing basis, measure and encapsulate knowledge, share it, and respond to issues that people care about.... It will be a framework for communication, decision support, understanding geographic science, and educating our children."

Jack Dangermond, 2017

Geographic Information Systems (GIS) are described by **ESRI:** perhaps the largest global provider of GIS (in the form of cloud-based applications) as:
"a framework for gathering, managing, and analysing data. Rooted in the science of geography, GIS integrates many types of data. It analyses spatial location and organises layers of information into visualisations using maps and 3D scenes. With this unique capability, GIS reveals deeper insights into data, such as patterns, relationships, and situations—helping users make smarter decisions."

GIS is a powerful tool which can be used to investigate and explore the world. ESRI has made their ArcGIS Online family of apps, such as Survey123, Field Maps and StoryMaps available free of charge to all schools in EU countries (and further afield) so you can access them easily. GIS should also not be just 'something else to teach'. We hope you understand the potential of GIS to enable clearer teaching of subject content, so that your students' understanding is better, and your own teaching becomes more effective. A school's use of GIS needs to be embedded across the curriculum, and across subject teaching, and it **needs to be introduced to students in a staged process to avoid cognitive overload.**

We use a slightly broader definition of GIS, or the GI in our project title. This can include other data visualisation tools, including Gapminder's 'bubbles', Google's Public Data Explorer, Earth NullSchool, statistical atlases and mapping tools such as Kiln. We also use ESRI's StoryMaps.

The pedagogy link includes **dual coding:** one of the particular aspects of cognitive science which has a close connection with the use of GIS. Mayer and Anderson (1991) found that when verbal information was presented alongside relevant images, it became much more memorable. These images can be retained and amended to aid pupils in subsequent tasks. GIS uses words and 'pictures' including mapping and symbology together, and as such represents an ideal example of dual coding at work in the classroom. GIS tools display data in various forms, which can be collected by the students themselves in layers on top of a base map. Symbols can be used to identify patterns in the data, and spatial tools offer queries and other options for collating and displaying the data. The GI Pedagogy MOOC will allow you to develop your ability in each of these areas.

Teachers should also aim to use the opportunities that **GIS** provides to analyse real world data from a number of sources. Without providing regular opportunities to do this, GIS will remain the focus for an occasional lesson where students are introduced to elements of GIS, but are likely to forget them before they use it again.

Small steps need to be taken throughout the K7-K9 phase of education, and similar sequences of opportunities looked for at K10-13 (and during the teaching of relevant national qualifications) to explore the opportunities within your own school. Periodic review, and the steady acquisition of blocks of learning (schema) are important.

Source: https://upload.wikimedia.org/wikipedia/commons/8/8d/Gis.jpg

This toolkit is aimed at supporting teachers of all levels of experience but particularly early career teachers (ECT), onto the lower rungs of a ladder of expertise, so that they can gain familiarity with the use of GIS. We are concerned with effective approaches to moving from instructional use (so-called 'cookbook' recipes) towards using GIS to solve problems where there is not an obvious step-by-step approach provided, as may be used in the early stages of teaching with GIS.

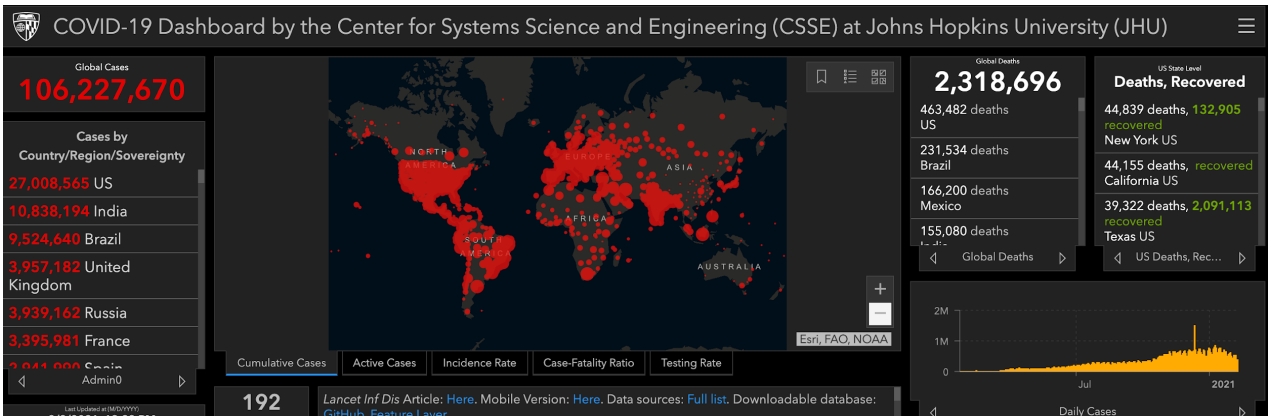
GIS are fundamental to our lives, and have tremendous value. ESRI enterprise refers to GIS as the **"science of where"**. https://www.esri.com/en-us/about/about-esri/overview
Teachers need to reinforce the power and relevance of GIS to students' own lived experience as part of their work with the tool, and **"light the fire"** in them to find out more. GIS offers learners **"a framework to organise, communicate, and understand the science of our world."**

Teaching with GIS should start as early as possible in students' school lives.
It has tremendous potential once the main steps in its usage have been grasped. In many ways, the use of GIS links perfectly with the development of teaching ability, as it requires the acquisition of knowledge in a series of steps. GIS use can also help your students achieve in terminal examinations, and many exam specifications now include elements of GIS in the examination papers and independent investigations. It is also ideal for use during geographical fieldwork.

It is also worth saying that **GIS** does not always need to involve a very high-tech approach to learning. **GIS** can be used for direct instruction and modelling from the front of the classroom, and doesn't always require you to move into an ICT suite.
As this toolkit is being compiled, GI is currently front and centre in the communication of the spread of the Coronavirus pandemic by epidemiologists. Just as Jon Snow used GI thinking to help uncover the cause of a cholera outbreak in 19th century London, present day.

Source: https://www.rcseng.ac.uk/library-and-publications/library/blog/mapping-disease-john-snow-and-cholera/
Web map produced by Brendan Conway http://arcg.is/1HXm94 adapted from the original John Snow data.
https://www.arcgis.com/home/webmap/viewer.html?webmap=6fb43b7db1d34716aad53583406f98b1&extent=-0.1434,51.5107,-0.1286,51.516 - an alternative option

During the Crimean war, Florence Nightingale created data visualisations using patient data. Contemporary physicians are using modern GIS tools, such as those at Johns Hopkins University. Their dashboard, created using ESRI mapping, has been viewed hundreds of millions of times. Our World in Data has also produced a similar map showing the spread in different countries. This is perhaps the most famous of the maps linked to the spread of COVID-19.



Source: https://coronavirus.jhu.edu/map.html

Our project will equip you with the confidence to use this powerful tool, along with your chosen discipline's powerful knowledge to develop powerful pedagogy for the classroom. The project explores the application of the development of schema and use of modelling which mirrors the principles developed by Rosenshine: the aim being to guide you up a series of steps which ***will allow you to learn how to use GIS without exceeding your own existing cognitive load***. At each stage, we will explore how using GIS can improve the overall understanding of not only GIS and its use, but also some effective strategies for taking the learners along with you on the journey, and it is a journey as there is always something new to learn and no definitive end.

4 Setting out your pedagogical intent

This toolkit is not part of just 'another course about GIS', and doesn't consist of a long list of GIS tools and resources that have already been produced by others. ESRI, other teachers and earlier ERASMUS projects have created numerous GIS resources and lists of that kind - they also date quite quickly as new tools emerge all the time.

*We will provide links to some of the key documents and tools in the **References** section at the end of this document.*

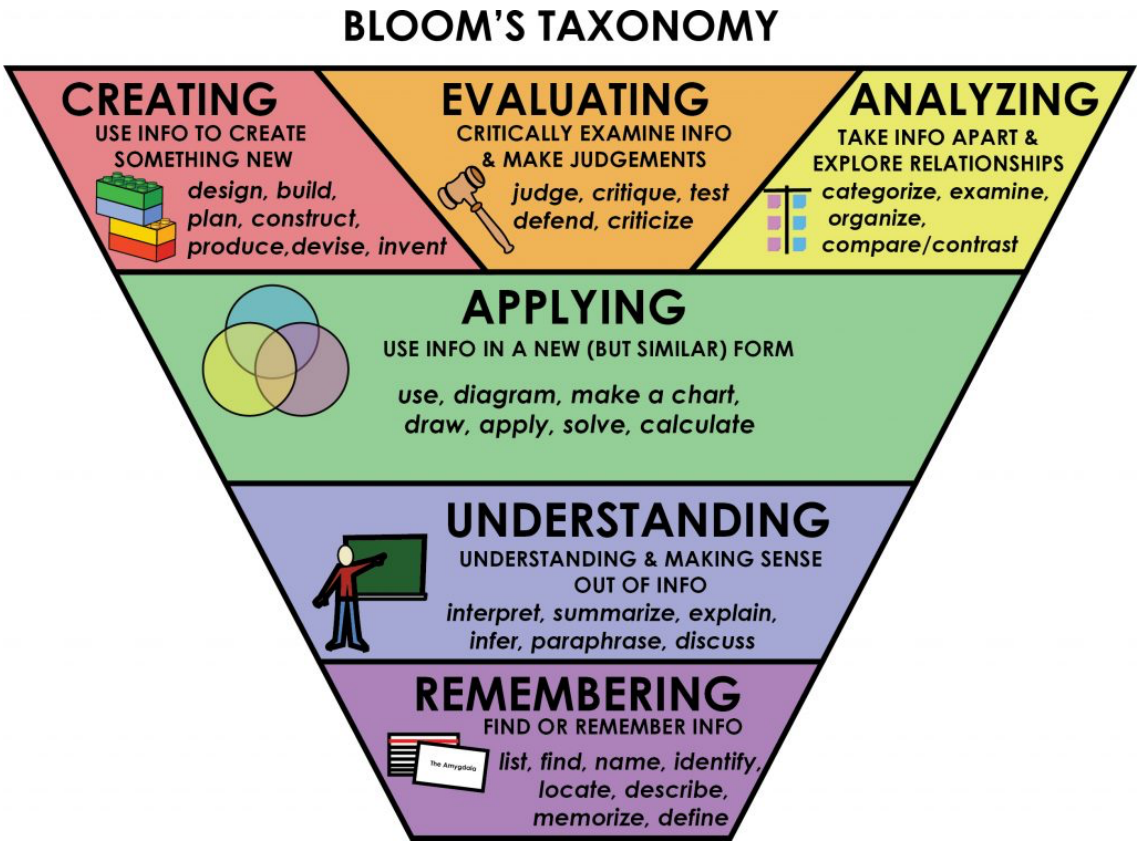
Our intention with GI Pedagogy is ultimately that when you consider how to teach any topic, you **consider making use of GIS** in some way, and that your classroom usage of, and students' exposure to GIS builds up over time. In doing so, your students and yourself will move towards a situation where the use of GIS becomes automatic, and doesn't require much time, thought or attention. The steps to this phase of **automaticity** will include modelling tasks, explaining concepts, checking students' understanding (asking lots of questions) and deliberate practice. For this to take place, you need to gain **confidence** before you can help learners gain confidence. You need to find out what the students actually know before, during and after the lessons where you are using GIS.

The contents of this toolkit have been developed following an earlier literature review, which resulted in a number of recommendations drawn from over 100 research papers. In this toolkit, we make particular reference to **Rosenshine's Principles of Instruction**. The toolkit suggests methods teachers could use to develop effective ways to build **schema**, which are building blocks to learning. GIS use requires the acquisition of a range of skills and knowledge that are needed to use the tool effectively, and these are built up in a series of steps.

Our project references important GIS skills and knowledge, but **focuses on the pedagogy of GIS usage in the classroom**, rather than providing worksheets and other materials, as with its precursor GI Learner (https://www.gilearner.ugent.be/) or be focused on **blended learning** (although we recognise that many schools are now required to use this as a result of COVID-19).

Before we, as teachers, start working with GIS, we need to consider our own **pedagogical intent**.

The diagram below, which is based on Bloom's taxonomy (originally created in 1956 but updated several times since) explores some of the pedagogical intentions we may have, and the activities that might be required to meet them. You may wish to consider which of these you have previously employed in a lesson where GIS was used. If you have little experience of using GIS you may find it helpful to consider which of these you think GIS may help with.



Source: https://www.toppr.com/bytes/wp-content/uploads/2019/06/Bloom-Taxanomy-1024x751.jpg

Our project references important GIS skills and knowledge, but **focuses on the pedagogy of GIS usage in the classroom**, rather than providing worksheets and other materials, as with its precursor GI Learner (https://www.gilearner.ugent.be/) there is also a potential for outcomes to support **blended learning** (we recognise that many schools have been, or are being required to use this as a result of COVID-19).

We are of the opinion that when using GIS it is advisable to adopt pedagogical practises which take into account the findings of **cognitive science** (especially the interaction of **working**

memory and long-term memory, and the building of **schema**). This will allow you to **move from novice to expert** in your own use of GIS, but also in your wider practice.

We have based our thinking on **evidence-led approaches** and effective learning techniques. *We have tried to avoid the polarisation of traditional and progressive methods, as each may have something to offer in different scenarios.* We respond to the problem that collaborative learning sometimes seems as if not all students learn.

Rosenshine's ten principles underpin **our work** on the GI Pedagogy project and were a starting point for our thinking about the project. The principles involve a number of specific actions, such as introducing new material in small steps and **frequent assessment of student understanding** (which needs careful planning). Difficult tasks should be scaffolded following initial teacher questioning to identify the level of scaffolding that is required. One of the great contributions that Rosenshine's work has given us is a **vocabulary** which we can now use when we are discussing such pedagogical choices that teachers make whenever we are planning a new unit of work, and helping students to achieve **automaticity,** so that they don't need to think about how they carry out certain GIS functions and tasks.

This includes a number of key terms such as:

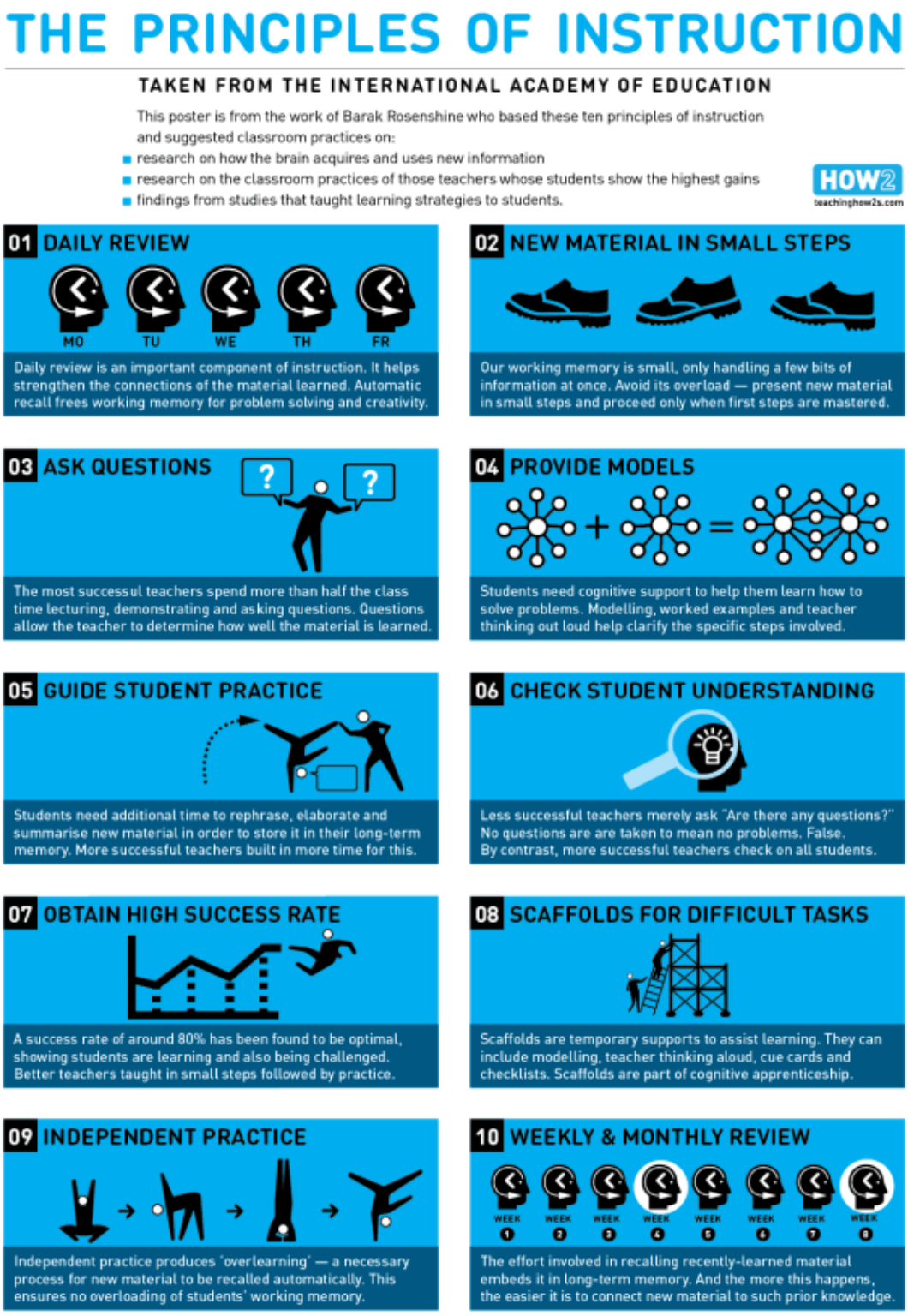
Deliberate practice - this needs to be part of your teaching approach when using GIS, with students being guided in a very focussed way for a period of time.

Retrieval practice - mastery of GIS involves the need to return to the work several times, building in new knowledge each time (iteration) and to offer opportunities to assess whether students have understood a particular element of the work. There needs to be opportunities for students to be **critical** of their learning as well through the process

Interleaving - where students mix, or **interleave**, multiple subjects or topics while they study GIS in order to improve their **understanding**. Students need to move their understanding of any new knowledge or topic they are learning from **working memory** into **long term memory.**

Schema - a block of knowledge - Rosenshine defines it as a well-connected network of ideas. As **schemata** are acquired, students begin to make connections for themselves.

Such activities are also important for effective embedding and avoiding the issue of GIS as a bolt-on activity.



Source: https://www.aft.org/sites/default/files/periodicals/Rosenshine.pdf

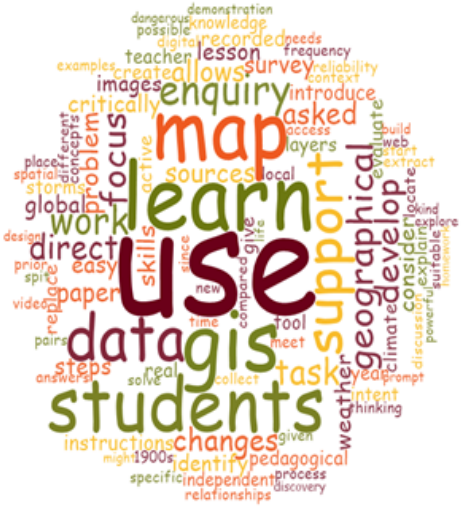
Stringer et al. (2019) suggested **four recommendations for using technology** (which could also include GIS):

1. Consider how technology is going to improve teaching and learning before introducing it.
2. Develop a clear rationale for improving the existing learning (which requires an assessment of the existing learning, its strengths and weaknesses).
3. Consider ways to improve the impact of pupil practice.
4. Address improving assessment and feedback.

There is also the idea of 'scaffolded freedom' that is worth exploring further - providing learners with the confidence to explore. The final 'step' of our model is a starting point for this sort of activity.

It is also worth saying that GIS has developed so quickly that the technology now facilitates different types of learning and added value that would be unthinkable just a few years ago. There should also be opportunities for collaborative learning where appropriate. Our model doesn't remove from the teacher the final decision on what is appropriate in their own context with the students that they know better than anyone else, but it should also encourage teachers to be ambitious in their use of GIS. This handing over of agency from the teacher to the student requires them to be confident.

A **small-scale research survey** was carried out as part of the **GI Pedagogy** project. We contacted a group of **22 teachers from several EU countries** who were identified, or self-identified as 'expert users'. When these teachers were asked about effective practice in GIS use, they mentioned the pedagogical techniques they were using which they felt were the most effective. We used these outputs to help inform the development of our model.



GI Pedagogy: Small scale survey of Teachers – a summary of results

Use of GIS	Teacher led Instruction (TI)	Student based enquiry (SE)
Intent: lesson Objectives	Curriculum knowledge focus	Use of GIS as a skill
Implementation: teacher input	**Instruction sheet, video instructions,** demonstrate and **model tasks** with an example, **down load apps,** explain, informal guidance, breaks and discuss + share ideas, give map, **paper instructions,** link to suitable data to prepare for a debate	**Instruction guides + virtual forum, video instructions,** use and model **examples** to explain in small steps use of GIS, **design a web quest,** provide **suitable map** (one story map) – use QR code, informal guidance, support, coaching – problem, enquiry, learn how to use GIS with students, **technical support, GIS manual.**
Impact: student learning	Use **GIS tools** including elevation, **map layers,** use **apps** such as **survey 123, analyse data sets,** use structured tasks, comparisons, **ask questions, debate, chunk** material	**Project, investigation,** challenge, **map data layers** to **analyse patterns,** create **story maps, answer questions**
Impact: type of learning	Curriculum knowledge (Geography) focus	Curriculum skills, GIS skills – most mention critical/problems
Overview	**More frequent integration** into the curriculum - smaller informal use, ask **questions + debate issues** – tool to interpret **curriculum content knowledge, less technical** GIS skills focus	**Less frequent, enquiry-based projects, web quest,** manuals to support, maps to support spatial literacy skills and **independent** discovery to explore and create **story maps** – informal facilitated written instruction, technical focus, as a tool for critical and spatial thinking skills.
Missing	Absence of field work examples – influence of pandemic? Focus: • **Physical** not Human Geography • **student use** not teachers' teaching tool	
Pedagogy surmised	**Integrated use of GIS** in teaching curriculum content – Powerful Geographical Knowledge and Powerful Pedagogy = to develop student use	**Enquiry-based project investigations** using **GIS tools** – independent, supporting **learning resources** such as WebQuest, structured tasks, story maps for student use

Source: Sophie Wilson, using data from the small-scale research survey (2020)

We contend that GIS needs to become **part of every teacher's personal teaching toolkit** because the widespread use of GIS by business is an essential underpinning to all of our lives. Students need to learn with and about GIS. **Learning is only good if it is effective**, so we would recommend that pupil-centred learning and opportunities for students to explore GIS without direct teacher instruction should come later in the process as pupils are unlikely to have the expertise to proceed very far with the technology without guidance until they develop a certain level of understanding. The **use** of GIS for direct instruction is as valid a **use** of the technology as the more problem-solving techniques we move onto. Our model starts with

simpler steps then, with front of class teaching and modelling of the stages required before students are taken further. If students are introduced to GIS regularly, this will take place at a faster rate as knowledge needs to be retrieved regularly for it to become part of long-term memory. When teaching with GIS, do so explicitly, to make students aware of it. It should become part of the everyday experience for students.

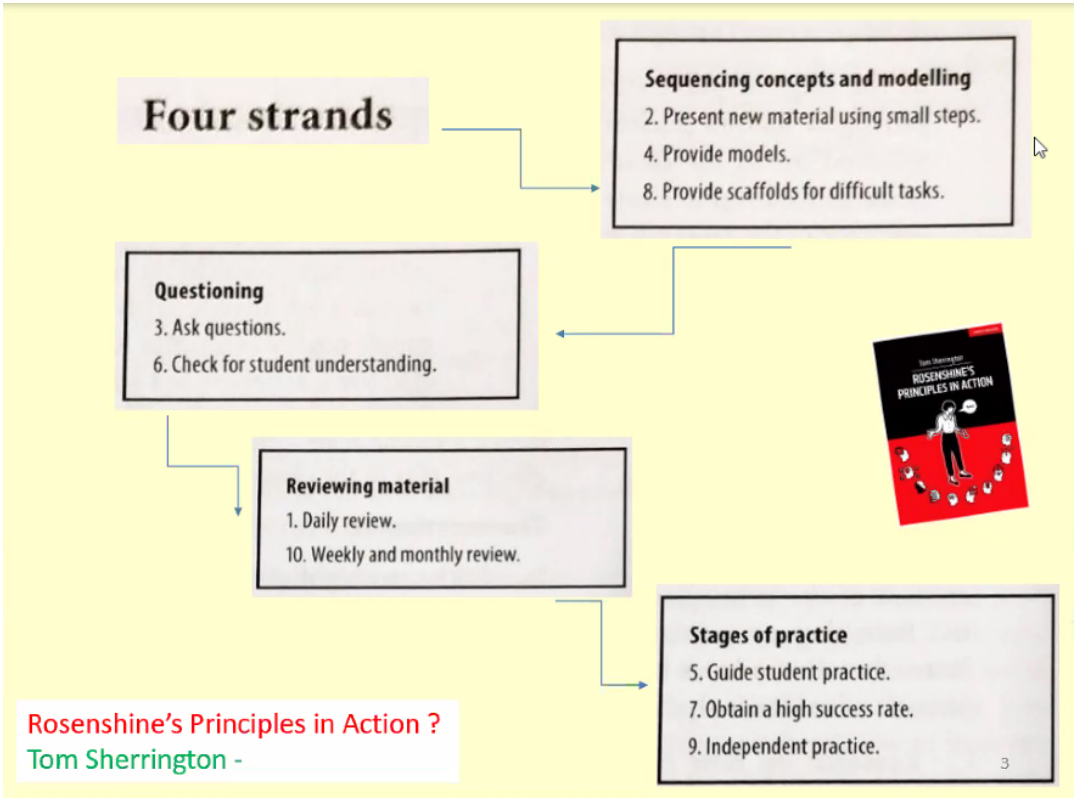
Teachers also need to develop agency in their own use of technology by building their own confidence in its use. Generative learning connects with the use of GIS, as it involves learners integrating new knowledge with existing schema.

Consider
What topics, that are part of your current curriculum, do you think that GIS could help you to teach in a more creative way?

5 Adapting Rosenshine's 10 principles

Rosenshine's principles are not GIS specific, but for our project we considered how they could be applied to teaching ***about and with GIS***. Rosenshine (2012) tells us that the best teachers ask lots of questions, and **interact with the students at each stage.** The stepped approach to learning is not confined to the students: teachers should also follow this approach when developing their own competence, according to the TPACK model, and this should be part of your own curriculum making. Teachers make pedagogical decisions about how the interactions are best achieved within the constraints of time, and the different needs of each student.

Tom Sherrington explored the idea of combining the principles of **Rosenshine** into four strands in 2020 to provide a possible workflow for teachers. This does not involve merging the principles together, but recognising that some of them are complementary. This is not a checklist, but a framework for introducing new knowledge. Sophie Wilson explored this in her own research.



Source: Sophie Wilson

When Rosenshine talks about **reviewing** material (and student progress), we consider this to be a **review of the GIS skills and knowledge** as well as the linked subject content that is being covered. The term **'daily review'** will for many subjects refer more to short term and periodic reviews rather than literally reviews taking place each day.

Scaffolding is needed for **all** new learners, including teachers. Any GIS task needs to be modelled first, followed by the use of a series of steps through which students and teachers work to develop their understanding. Videos can be used to introduce students to the stages that include modelling - this connects with some of the blended learning approaches that are having to be adopted in 2020-1 as a result of the COVID-19 pandemic, but would also link with the use of MOOC. It is easy to get lost in the **technical** and practical aspects of using a GIS tool and take a lot of time to unpick a task. These steps need to be thought about when planning a lesson sequence, just as a teacher would with any planning, and teachers need confidence that they can complete them in front of a class. Sweller uses the phrase **"scaffolded freedom"** to reflect the careful use of support that is carefully removed, and may be removed at different rates for particular groups / individuals as they are no longer required, and competency increases. We include this in our model.

6 Introducing our GI Pedagogy model

The GI-Pedagogy model aims to bridge the gap between the early adopters who are confident with the technology, and those who have never used GIS before and are looking to start. The model is innovative not because it is completely new (which would be quite difficult to achieve), but because we have looked to apply the work of Rosenshine and others to the pedagogy of using GIS.

The aim is to demystify the use of GIS away from something very 'technical' towards it being a regularly used tool for teaching a number of subjects. GIS could be said to be the perfect vehicle for teaching someone how to teach. As students are introduced to GIS, they develop a number of small building blocks of knowledge (these steps are known as **schema** once they are acquired and ready for use). Our methodology suggests a scaffold for teachers to use (and to remove as confidence and ability improves).

This stepped approach avoids cognitive overload as well, allowing new material to move from working into long-term memory through the use of schema, and the teacher modelling the steps that are needed.

Lessons (and activities within lessons) need to be broken down into **steps** so that you as the teacher **understand why they work, and ensure that they are effective**.

In his book 'Rosenshine's Principles in Action', Tom Sherrington (2019) identifies **a series of steps** which occur when a student (or teacher) learns something:

- Conceptual information enters working memory from the classroom environment: via a resource or a teacher.
- Working memory is finite and quite small; therefore, we can only take in a limited amount of this information at any one time.
- Our long-term memory is unlimited, and as we process information it is stored in our long-term memory.
- We retrieve relevant information from our long-term memory into our working memory when it is needed.

- **We organise this information into schema and build these schema in long-term memory. New information typically only becomes stored if we can connect it to knowledge we already have; therefore, prior knowledge significantly influences our capacity to learn.**
- The more well connected our schema are, the easier it is for us to make sense of and organise new information, as it relates to our existing schema, and we start to be able to explore our knowledge and retrieve it more fluently.
- We will forget information that we don't store successfully in a meaningful schema when first introduced to it, or if we don't retrieve it frequently enough. This is why frequent exposure to GIS is vital if we are to build schema.
- If a schema contains incorrect information, we can't simply 'overwrite' it, but need to unpick and fully re-learn the correct schema instead. The teacher is still required here.

The starting point for the thinking behind our model was a series of steps. The **steps in our model** are drawn from the principles of Rosenshine. A few caveats would be that Rosenshine's principles are **not a model**. Our MOOC will explore the model and its steps. As teachers begin to imagine learners ascending the steps, they may also become more critical of existing materials that are available which will help in their selection of, and development of materials for use in their own classroom. An important element of the use of GIS is that it should be involved in the development of a narrative, identified by the teacher as a way to introduce a particular topic. Stories are powerful, and our model has the construction of a narrative as its basis: how can successful GIS lessons be created in your classroom? Are you ready to ascend the ***'stairway to (GIS) heaven'?***

The motivation in taking the first step up is the desire to learn how to teach with GIS.

We advise starting on the lowest step and feeling comfortable there before taking the next step up. Don't rush up the steps. With each step up there is an increase in 'difficulty' or complexity in the use of GIS. There is a little ramp for providing a helping hand. You can also step back down for a while if things get a little too difficult, to remind yourself what the previous step was. Once each step up has been taken, teachers can begin to explore the alternative methods of pedagogy, which are explored in the MOOC and suggested by our expert group of teachers.

S in GIS stands for **system.**

S in our model can also stand for **steps** of course and also **scaffolding.**

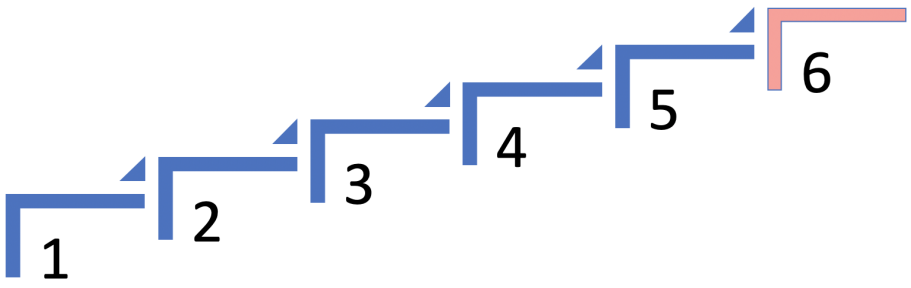
S can also stand for **schema / schemata**: the interconnected blocks of knowledge which are acquired at each level.

S is also about **solutions** to problems which GIS can help to produce.

And finally, the S can stand for the **stories** which are told using GIS: the narratives developed by teachers and learners.

Also S **= sustainability**

Our final thinking can be represented by this diagram:



2019-1-UK01-KA203-061576

Co-funded by the Erasmus+ Programme of the European Union

You will notice the  between each step - these represent opportunities for **checking understanding** before moving up, and also the opportunity to slide back down if required. Steps may also be missed out by groups who may have already acquired schema, but may also be visited several times during a lesson sequence.

As students are introduced to GIS, they develop a number of small building blocks of knowledge (these steps are known as schema). For the purpose of the toolkit, GIS teaching involves the acquisition of **Geographical Information Schemata.**
Steps are built into the teaching of GIS, mirroring the pedagogical approach that we are suggesting in our model.

Our model also has an important Step 0, before we even start climbing: this would involve a check on prior learning.

We suggest five steps leading to the potential for a 6th step which could take the form of either a student presentation or some sort of assessment. These are best represented in the lesson planning using enquiry questions.

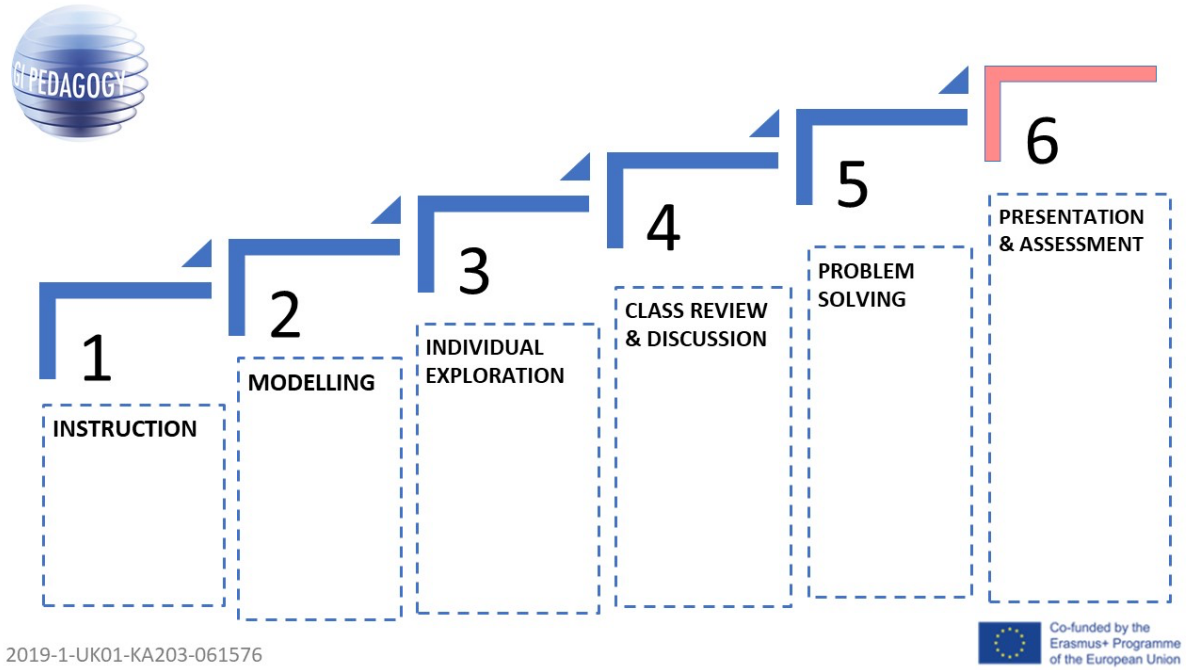
Step 1: Direct instruction / teacher facilitated stage - this is where schema building begins. Present new material.
Step 2: Modelling / Scaffolding, with review and questioning – what data are needed?
Step 3: Individual exploration
Step 4: Review - discussion
Step 5: Problem-solving
Step 6: Presentation/Assessment (Peer assessment possible too) and sharing of outcomes.This will also be the stage where students may feel secure enough to start their own exploration.

Two key areas to remember with the model:

 = checking understanding - do not step up until you feel comfortable with the previous step and remember that you can always go back down again, or start each lesson in a sequence of lessons by recapping and checking schema are in place.

The steps are not intended to end at number 6. This may represent a 'landing' stage before a whole new flight of stairs begins.

If required, a handrail is available, running the length of the steps to help people climb them. Users are welcome to use this if appropriate. This can also be used to slide down again if required.



To assist in (y)our thinking around the model, we are going to introduce some worked examples in the form of **vignettes** developed by experienced teachers. We will use these to communicate what we feel are effective examples, which are based on our model. Vignettes are narratives, transparent in content, with web references, interwoven with comprehension questions, in which the learner participates in hypothesis testing and problem solving in the first person (deep learning). They are thematically oriented, without exhausting a topic, and may include simulations. They favour making predictions with knowledge. Thus, they integrate the point of view of the teacher and the student, taking into account the teacher's and the student's needs (Chaloupka & Koppi, 1998).

They are also a way of assessment to measure affective goals, such as the motivation to learn, evidence of problem solving and critical thinking (Jeffries & Maeder, 2005). They are an effective teaching model.

6.1 Case Study 1: Exploring the rivers of London

Rivers are a common topic in the geography curriculum in many EU countries. All students and teachers live within the catchment of a river. Brendan Conway from Cobham School, Surrey, UK used our staged approach to investigate a local river, and explore watersheds. A video and web map are included here for further investigation:
https://www.rgs.org/RGS/media/RGS-Media-Library/Schools/Teaching%20resources/Brendan-Conway-3-Nov-2020-HHQ.mp4
https://www.arcgis.com/apps/webappviewer/index.html?id=581de3f4019b4277b4c4a4305c8ad4a1&extent=-284648.2864%2C6342522.1299%2C155628.9965%2C7105669.4203%2C102100

Student led learning doesn't always lead to the development of strong schema, as there may not have been a previous modelling of appropriate schema. Acquisition requires repetition of GIS use through various years of K7-K12.
We are aiming for **automaticity:** that the use of GIS becomes embedded and students can achieve steps e.g. symbolising data, without having to think about how to do it.
Joseph Kerski suggests that the instructional use of GIS requires a stepped approach with 5 levels (which are best used to respond to a real world problem):

1. Presentation of data
2. Scripted activity
3. Expanded script
4. Directed project
5. Custom project

The toolkit is aimed to provide teachers with the pedagogy that is needed to introduce GIS use. Read more about Brendan's work here:
https://storymaps.arcgis.com/stories/2ebd0ba970094e56b36f092b10e5b36b

6.2 Case Study 2: Global Atmospheric Circulation Model

Let's take the teaching of **global atmospheric circulation** as a second example. This is a difficult concept to teach because of the scale of the movement, and the different interactions at ground level and higher up in the atmosphere. It is important that students recognise **why** we are using GIS to explore any particular tool. This example uses a data visualisation tool called Earth NullSchool. https://earth.nullschool.net/

Data, which is just a few hours old, is geo-referenced and is then mapped. This demonstrates that GIS aren't necessarily static maps either, they can be dynamic in nature. Changing the layers allows students to see the position of the Intertropical Convergence Zone, position of clouds and precipitable water, patterns of humidity and also high level winds including the jet stream(s).

More examples will be located on our website.

www.gi-pedagagy.eu

7 Ideas for embedding the use of GIS in your subject pedagogy

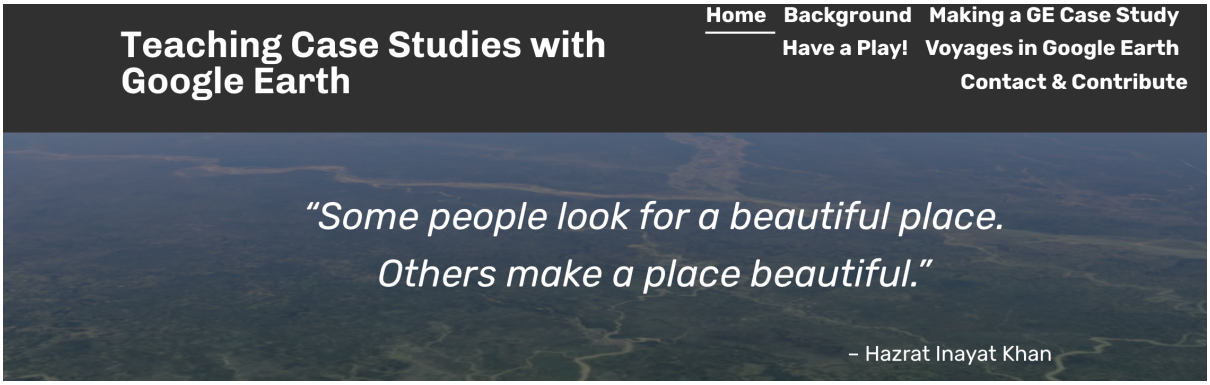
GIS needs to become part of the 'furniture' in your own classroom. Maps are often used in the classroom, but rather than using paper maps, Google Earth or atlases to obtain maps, GIS should **always** be used to provide the maps that students use whenever they are required. Some examples of GI(S) apps / websites / tools that might be useful in different learning settings are listed below:

7.1 ArcGIS Online

AGOL is free for most schools in the EU. UK schools' support http://schools.esriuk.com/ and Spanish schools https://colegios.esri.es/ (useful for Spanish lessons), ask your national ESRI (https://www.esri.com/en-us/about/about-esri/europe) distributor for access.
It also includes ArcGIS Pro, for further GIS analysis.

7.2 Google Earth suite

Earth for Chrome https://earth.google.com/web/
This now includes a new 'Projects' option, which allows for the creation of tours. Some have been collected by Andy Funnell: https://earthcasestudies.wordpress.com/



Google Earth Studio: https://earth.google.com/studio/docs/
Google Earth has developed a great deal from its initial launch in 2005 and is now based in a browser rather than a download. Studio offers the chance to create stories similar in style to StoryMaps, with aerial views and video facilities.

Google Earth Pro

A free download is still available of an earlier iteration of Google Earth resembling the original version: https://www.google.co.uk/earth/download/gep/agree.html and with some of the same functionality.

7.3 Digimap for Schools:

https://digimapforschools.edina.ac.uk/ - provides Ordnance Survey coverage of the UK, and OSM coverage of the rest of the world, along with mapping tools. Used by over 1000 schools in the UK.

7.4 QGIS

QGIS is working as a desktop GIS with lots of functionality, pupils will need some time and introduction to be able to benefit from these functionalities. Recommended for higher classes with some GIS experience. Download from the official Web page to install it locally (check the QGIS release version) https://www.qgis.org/en/site/forusers/alldownloads.html and install it according to your operating system.

Documentation for QGIS https://docs.qgis.org/testing/en/docs/index.html and the QGIS testing user guide https://docs.qgis.org/testing/pdf/en/QGIS-testing-UserGuide-en.pdf are also available. This is an open source GIS.

7.5 Fieldwork - data acquisition

Within fieldwork, consider the use of apps which can be used to collect fieldwork data.

- Survey123: https://survey123.arcgis.com/
- Collector: https://www.esri.com/en-us/arcgis/products/arcgis-collector/overview
- Google maps: http://maps.google.com
- Bing maps (has an OS layer option for the UK): https://www.bing.com/maps
- ONA: https://ona.io/home/
- ODK Collect: http://opendatakit.org/ (for Android)
- QField collector: https://qfield.org (for Android)

8 GIS is the perfect vehicle for teaching you how to teach.

Along with cognitive science, another idea that is currently considered to be of particular value in education is that of **powerful knowledge**. This has developed from the thinking of Michael Young (2013) and others.

This is needed in order to make full use of the potential of the use of GIS, within any academic subject.

The GeoCapabilities project (Solem et al, 2013; Biddulph et al., 2020) has explored the development of such knowledge within geography.

In a talk for the Geographical Association's GEO project, Joseph Kerski talked through his own approach to teaching with GIS. As someone who has used GIS throughout his life, he explored the key approaches that had worked.

Source: https://geographyeducationonline.org/event/a-focus-on-change-over-space-and-time-using-web-gis-tools-and-spatial-data

Another aspect of this is that the teacher constantly monitors the use that students are making of GIS and suggests where they can go next. This is what we might call "powerful pedagogy": pedagogy that leads to critical thinking (Kim and Bednarz 2013; Bearman 2016; Biddulph et al, 2020) and better decision making. We are focussing on the acquisition of powerful ***GIS*** skills and knowledge.

Having acquired the skills and knowledge, agency needs to be passed towards the learner, as the confidence of both teachers and students develops.

This may be termed as **geo-literacy**, and the aim of the toolkit is to guide teachers towards becoming more literate in their use of mapping and geographical information.

Students need to understand something of the purpose of GIS before they start to produce their own maps, if they are to be of a high quality and use the full potential of the tool. This could include considering the way that data is best visualised. Students can visualise data without a major analysis and this is technically still "creating a map", but we hope that students will move to a point where they can make use of GIS and appreciate how to create the best map using appropriate symbology and analytical tools.

Questioning and fixing misconceptions are vital for the success of this toolkit. This needs to come before the application of the scaffolding.

A continuum of support is required for both teachers and students.

Our project focuses on the novice end of the teacher continuum, and also on Early Career Teachers rather than more experienced teachers. With some other GIS support the focus is on the more expert end.

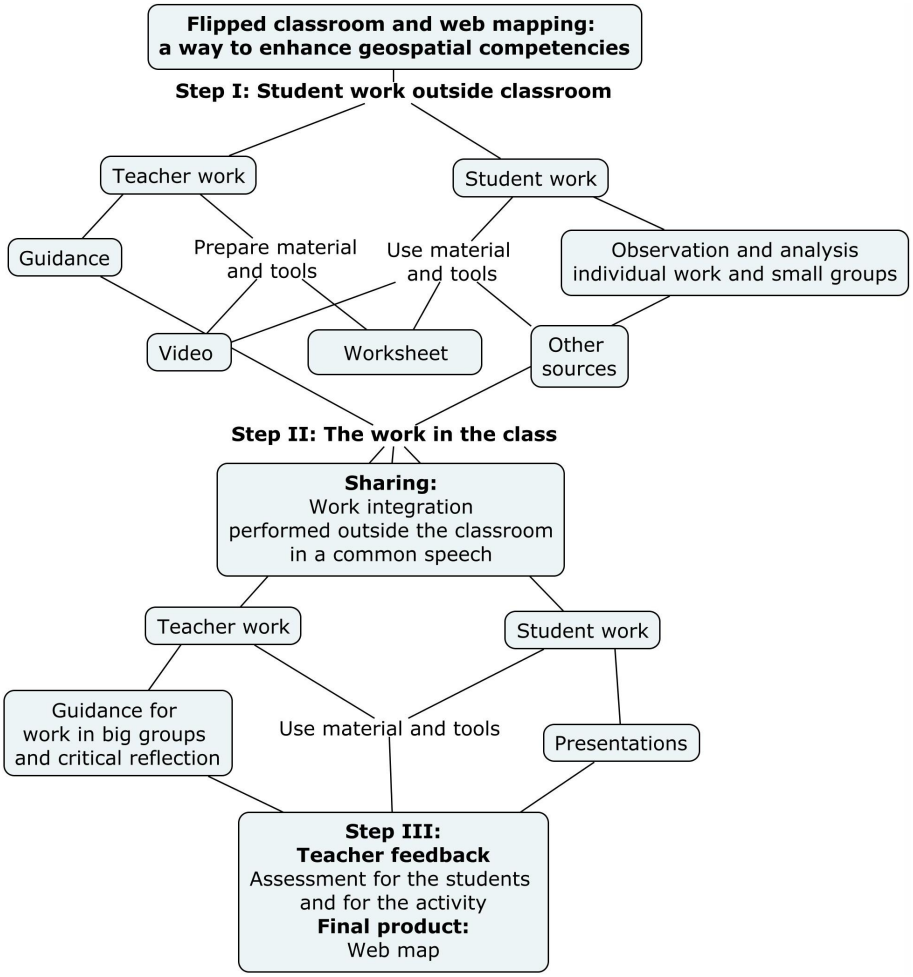
9 What is powerful pedagogy for GIS use?

Along with cognitive science, another idea that is currently considered to be of particular value in education is that of **powerful knowledge**. This has developed from the thinking of Michael Young. This is needed in order to make full use of the potential of the use of GIS,
The GeoCapabilities project provides more ideas in this area.
http://www.geocapabilities.org/
In a talk for the Geographical Association's GEO project, Joseph Kerski talked through his own approach to teaching with GIS. As someone who has used GIS throughout his life, this is worth watching.
https://geographyeducationonline.org/event/a-focus-on-change-over-space-and-time-using-web-gis-tools-and-spatial-data

Over time, as skills and knowledge are acquired, agency needs to be passed on to the learner, as the confidence of both teachers and students develops.

This may be termed as **geo-literacy**, and the aim of the toolkit is to guide teachers towards reaching this stage. Questioning and fixing misconceptions are vital for the success of this toolkit. This needs to come before the application of the scaffolding. A continuum of support is required. This toolkit suggests focusing on the novice end of ability with GIS, whereas with some other GIS support the focus is on the more expert end.

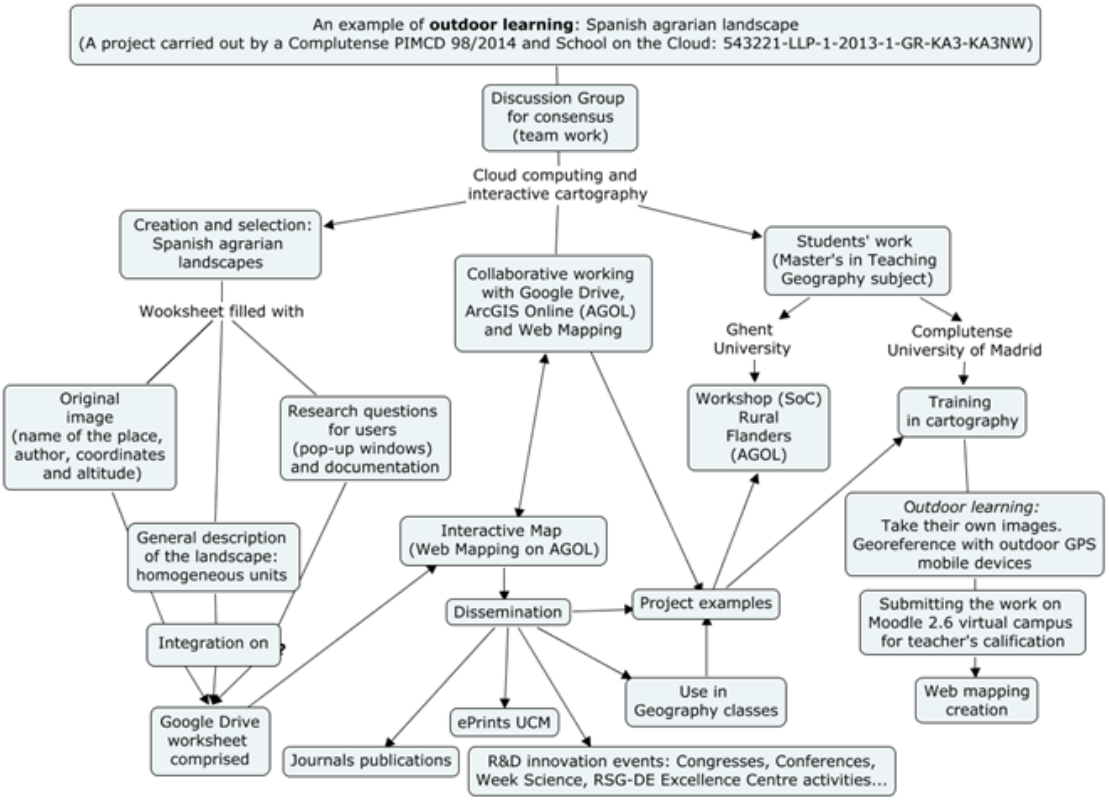
The revolution of geographic information and cloud computing enables new methodologies for learning in the classroom. Geospatial skills can be improved by browsing online web mapping. Two pillars are essential: development or use of the mapping itself, and critical reflection of the mapping. Geodata displayed on web maps allows us to obtain new insights and learning. Flipped classrooms allow a better optimization of time available in classrooms. The result has been the learning of the contents of the subject as well as the acquisition of geospatial and digital competencies. It can be concluded that cloud computing is an essential tool in 21st century university classrooms. This is what happened in the Geography subject of the master's degree for secondary school teachers. This model has been used on agrarian landscapes (Lázaro et al, 2016) integrating flipped classroom and Web GIS.



Source: Lázaro, De Miguel y González. (2015), p.86

The results are published on a web map.

https://ucmadrid.maps.arcgis.com/apps/Viewer/index.html?appid=ea9c8b352b60491b8741d5f6



Source: M.L. Lázaro, R. De Miguel and I. Buzo "Outdoor learning and geography on the Cloud: A challenge for the European network "School on the Cloud" (2016)

10 Building on the GI Learner aims

A learning line is a necessary frame for a lesson plan and an educational term that refers to progression in the construction of knowledge and skills throughout the whole curriculum. This learning line reflects an increasing level of complexity, ranging from easy (more basic skills and knowledge) to difficult (Zwartjes 2014), as well as age and capabilities of students. The ten GI Learner competencies for the learning line progression help students to participate and respond collaboratively based on civic responsibility, after acquiring the knowledge and the digital and spatial competencies necessary for this purpose. There are three levels of complexity: A, simple; B, medium and C, complex (the last should be achieved by the end of secondary school).

GI Learner Competencies

1	**Critically read, interpret cartographic and other visualisations in different media**	**Read, interpret**
	A: Read maps and other visualisations	Example: use legend, symbology ...
	B: Interpret maps and other visualisations	Example: use scale, orientation; understand meaning, spatial pattern and context of a map
	C: Be critically aware of sources of information and their reliability	Example: critically evaluate maps identifying attributes, representations (e.g. inappropriate use of symbology, or stereotyping) and metadata of the maps
2	**Be aware of geographic information and its representation using GI and GIS.**	**Learn about, understand**
	A: Recognize geographical (location-based) and non-geographical information	Example: describe GPS, GIS, Internet interfaces; be able to identify geo-referenced information
	B: Demonstrate that geographical information can be represented in some ways	Example: employ some different representations of information (maps, charts, tables, satellite images...)
	C: Be critically aware that geographic information can be represented in many different ways	Example: be able to evaluate and apply a variety of GI data representations

3	**Visually communicate geographic information**	**Communicate, transmit**
	A: Transmit basic geographic information	Example: produce a mental map, be aware of your own position
	B:Communicate using geographic information in suitable forms	Example: basic map production for a target audience - using old and new media, Share results with target group
	C: Use GI to exchange in dialogue with others	Example: discuss outcomes like survey results/maps online or in class, referring to a problem in your own environment
4	**Describe and use examples of GI applications in daily life and in society**	**Describe**
	A: Be aware of GI applications	Example: know about GPS-related/locational (social networking) applications including Google Earth; produce a listing of known GI applications or find them on the internet/cloud
	B: Use some examples of (daily life) GI applications	Example: problem-solving oriented with GI application like navigating; use an app to read the weather, environmental quality, travel planner
	C: Demonstrate why and how GI applications are useful for society	Example: assess the functionality and use for society of a GI application (emergency services, police, precision agriculture, environmental planning, civil engineering, transport, research) and present the results
5	**Use (freely available) GI interfaces**	**Apply, use**
	A: Perform simple geographical tasks with the help of a GI interface	Example: Find your house in a digital earth browser; finding a certain location; measuring the distance between two points by different means; use applications for mobile phones (ex. GPS) to locate a place
	B: Use more than one GI interface and its features	Example: collect data and compare to set the best route from school to home and back; get a topographical map for a walk
	C: Effectively solve problems using a wide variety of GI interfaces	Example: Find and use data from various data portals (SDI) to look for the best facilities of a specific region, or for the 'best' place to live using parameters like infrastructure, noise, open spaces, ...

6	**Carry out own (primary) data capture**	**Produce, gather and select**
	A: Collect simple data	Example: gather data during fieldwork (coordinates, pictures, comments...) e.g. sound data to analyse impacts of traffic; map attractive places for children in your city
	B: Compare different qualitative and quantitative data and select an appropriate data gathering approach, tool etc.	Example: when investigating environmental factors choose what data is needed
	C: Solve issues concerning data gathering and select the most suitable alternative approaches to data capture	Example: design a methodology which explains the data collection for land use change, like how to collect data from different sources and classify them appropriately
7	**Be able to identify and evaluate (secondary) data**	**Identify data quality**
	A: Locate and obtain data from source maps (different visualisations)	Example: Find and download data on migration and be able to use it
	B: Acknowledge that there is different quality in data, not everything is useful	Example: Identify multiple data sources for example of population or pollution and be able to assess their level (scale), detail, frequency, accuracy and other considerations; analyse different sources and decide which is the most useful
	C: Fully assess value / usefulness / quality of data	Example: Use data on climate change from ESA, IPCC compared to Facebook graphs
8	**Examine interrelationships**	**Analyse, relate**
	A: Recognise that items may, or may not, be related (connected) in different ways to one another	Example: recognize simple relationships between things, e.g. heat and sunshine, or city size and traffic jams // inverse relationships // some things are not related
	B: Demonstrate interrelationships between a variety of factors	Example: changes in environment, influence, connections and hierarchy of ecosystems
	C: Recognise different relationships and judge causes and effects	Example: Evolution of ecosystems over time is complex and is related to many variables; problem-oriented exploration of interrelationships like: where do my jeans or my mobile phone come from

9	**Extract new insight from analysis**	**Summarise, synthesise**
	A: Identify what the analysis says	Example: understand there are different types of climate
	B: Combine elements from the analysis to make sense of the outcomes	Example: realise that climate is changing
	C: Assess the analysis in depth, create new meaning and make links to the bigger picture	Example: responding and suggesting solutions on climate change
10	**Reflect and act with knowledge**	**Evaluate, action & decision making / applying in real world**
	A: Recognise the decisions that had to be made	
	B: Judge implications for individuals and society	
	C: Design future actions to stakeholders - including themselves	

Competency and school year to achieve it (according to the level of complexity)

Competency	K7-K8	K9	K10	K11	K12
1. Read, interpret	A	B	C		
2. Understand	A	B	C		
3. Communicate and transmit	A		B		C
4. Describe	A	B	C		
5. Apply, use	A	B	C		
6. Produce, gather and select	A		B		C
7. Identify data quality	A		B		C
8. Analyse / relate		A	B		C
9. Summarise / Synthesise			A	B	C
10. Evaluate/ take proper actions	A		B		C

Source: GI Learner. Zwartjes, L. and De Lázaro, M.L. (2019).

Students learn that geographic information shows not only where things are located, but why. Most students feel able to use an app, maps and images and show the results to other people, for example, indicating their way to school. The conclusions obtained in the whole process didn't just relate to geoinformation, but there were also technological and pedagogical aspects that students learned, all of them useful for learning to think critically.

11 The Concept Cube

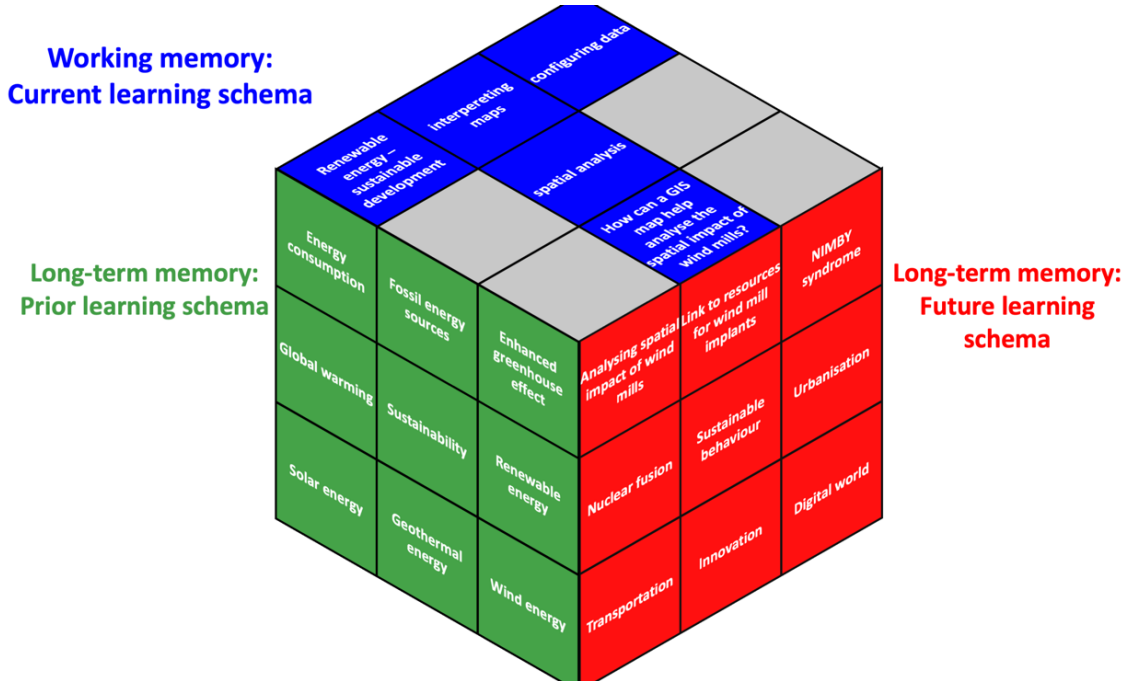
In our learning materials, we have made use of an interactive cube which visualises three areas of learning.

There are 3 coloured sides visible on the cube:

- Green: Long Term Memory - Prior-learning schema
- Blue: Working Memory - Current learning schema
- Red: Long Term Memory - Future learning schema

This is available as a download from the GI Pedagogy website, along with the information on how to create your own concept cubes by entering the information that is included in a particular task.

Each of our vignettes has a cube to show these three areas.



Example of the cube for the vignette on wind energy

12 Coda: COVID-19

This project has taken place against a backdrop of the emergence and global impact of COVID-19. Partners have worked virtually to develop these resources, and teachers in many countries now find themselves using blended learning approaches. The adoption of these approaches has been accelerated.

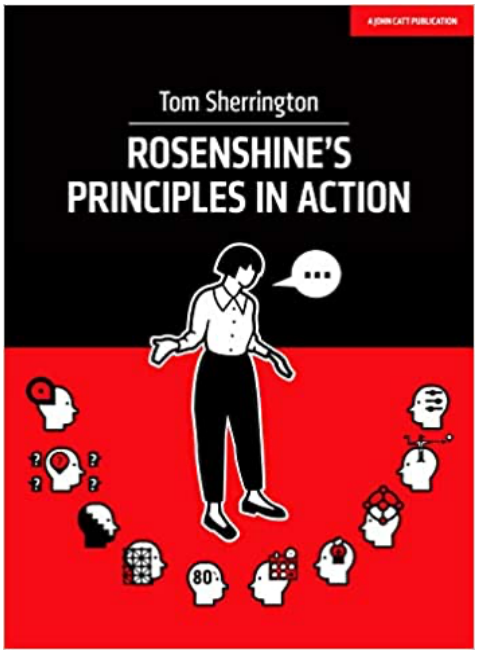
Schools will now be more familiar with the use of remote learning and may have accelerated the development of Bring your own Device policies.

How can schema continue to be developed in this context, without the same classroom dynamic, and the opportunities for teachers to see the learners' engagement with resources?

13 References & further reading

13.1 Cognitive load theory & Rosenhine's principles

Tom Sherrington (2019), 'Rosenshine's Principles in Action',



The key source book for the project, and this toolkit is:

This also has an accompanying Workbook available to help.

https://www.olicav.com/#/understanding-how-we-learn/

Generative Learning:
https://www.researchgate.net/publication/264233729_Learning_as_a_Generative_Activity_Eight_Learning_Strategies_that_Promote_Understanding

Geo talk by Joseph Kerski - produced for the Geographical Association's GEO website:

https://geographyeducationonline.org/event/a-focus-on-change-over-space-and-time-using-web-gis-tools-and-spatial-data
https://www.youtube.com/watch?v=kca6KiedDwU&feature=emb_logo
Field Studies Council session on GIS and fieldwork:

https://geographyeducationonline.org/event/embedding-gis-in-enquiry

Rosenshine, B. (2012) 'Principles of Instruction: Research-based Strategies that all Teachers Should Know'. American Educator Spring.

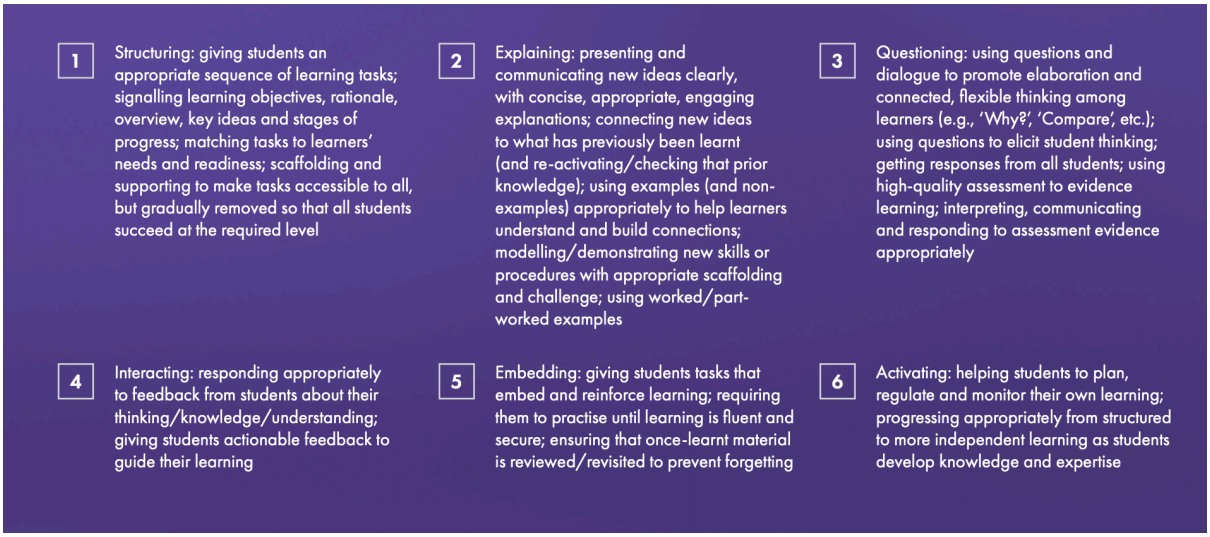
https://www.aft.org/sites/default/files/periodicals/Rosenshine.pdf - the original paper by Barak Rosenshine
https://teachinghow2s.com/blog/principles-of-instruction

13.2 The Great Teaching Toolkit

from Cambridge International provided some early inspiration for our thinking, as it involved a literature review

https://www.cambridgeinternational.org/Images/584543-great-teaching-toolkit-evidence-review.pdf

Dimension 4 of this document explores Hard Thinking and suggests 6 stages which we considered to be a valuable approach.



Great Teaching Toolkit - Dimension 4

https://www.cambridgeinternational.org/Images/584541-4.-activating-hard-thinking.pdf
https://www.cambridgeinternational.org/support-and-training-for-schools/teaching-cambridge-at-your-school/great-teaching-toolkit/

13.3 The toolkit refers to the following frameworks

Dynamic Model (Creemers and Kyriakides, 2011) which has eight classroom dimensions, ISTOF (Muijs et al, 2018) has seven components, ICALT (van de Grift et al. 2017) has six, Rosenshine (2010) has ten principles, and the Early Career Framework has eight standards.

Innovative Pedagogy and Theoretical Basis - a checksheet

https://docs.google.com/document/d/1iBhNOpikdp6UKpw7Y2omIEoaV2AwSaeJ/edit?rtpof=true

13.4 GI Learner project:

The vignettes created are partly based on lessons created for the GI Learner project.

https://www.gilearner.ugent.be/course/ - course materials.

https://www.researchgate.net/publication/312321204_The_GI-Learner_Approach_Learning_Lines_for_Geospatial_Thinking_in_Secondary_Schools

13.5 Other references

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14 Appendices

14.1 Map Viewers for EU countries

ArcGIS Online is free to all schools and can be used as a map viewer as well as offering more sophisticated analysis tools. Some countries also have their own mapping portals with a range of layers and images, made available following the INSPIRE directive.

From EUROSTAT side:
TENtec Interactive Map Viewer: Mobile and Transport:
https://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/map/mobile.html

Eurostat statistical organization: http://ec.europa.eu/eurostat/statistical-atlas/gis/viewer/?config=typologies.json&mids=BKGCNT,NUTS2016L2,CNTOVL&o=1,1,0.7&center=50.04099,19.94249,3&

Eurostat Regional Yearbook: http://ec.europa.eu/eurostat/statistical-atlas/gis/viewer/

Country Profile:
https://ec.europa.eu/eurostat/guip/introAction.do?profile=cpro&theme=eurind&lang=en

Students need to understand the GIS that makes a viewer work.

EU Country	Map Viewer
Austria	http://geoland.at (platform for 9 provinces' GI-platforms) http://austrianmap.at (topographic map with some functionality)
Belgium	Flanders: GeoPoint - http://geopunt.be Wallonia: https://geoportail.wallonie.be/home.html Brussels Capital Region: https://geobru.irisnet.be/en/ Belgium: http://geo.be - for visualising, not querying
Finland	PaikkaOppi: https://www.paikkaoppi.fi, for Finish schools. An example in English: https://www.paikkaoppi.fi/sv_SE/telling-about-finland/
France	Le portail national de la connaissance du territoire mis en œuvre par l'IGN https://www.geoportail.gouv.fr/
Norway	Maps catalogue: https://www.geonorge.no/

Romania	http://geoportal.igr.ro/ http://virtualromania.org/maps/
Spain	SignA: http://signa.ign.es/signa/Pege.aspx Iberpix: https://www.ign.es/iberpix2/visor/ Cartociudad: http://www.cartociudad.es/visor/ https://www.ign.es/web/comparador_pnoa/index.htm Anaglifos 3D: http://www.ign.es/3d-stereo/l Most of these Spanish viewers allow downloading layers with the spatial reference for later use on a GIS.
UK	Digimap for Schools (and the linked product DataNation) is a subscription based service within the UK (although it has mapping of the whole world) Map Viewer Scotland: https://maps.nls.uk/geo/explore/3d/#distance=2000000&tilt=0.90&heading=0.0000&lat=55.00000&lon=-3.50000&layers=1&exag=1 Old and current maps side by side https://maps.nls.uk/geo/explore/side-by-side/#zoom=10&lat=53.40691&lon=-2.25993&layers=1&right=ESRIWorld Geology viewers: https://www.bgs.ac.uk/geological-data/map-viewers/ Soil viewer http://www.ukso.org/

Use GIS maps in **web viewers** to introduce new concepts, (explicitly referring to the fact that they are GIS) e.g. AGOL; open access.

Examples:

- https://media.hhmi.org/biointeractive/earthviewer_web/earthviewer.html - Earth Viewer
- https://earth.nullschool.net/ to teach atmospheric circulation; thermohaline circulation; extreme weather (tropical storms; ENSO)
- How accurate is your mental map?: http://maps.ugent.be/
- The True Size Of (https://thetruesize.com)to teach scale; map projections
- FlightRadar24 (https://www.flightradar24.com) to teach latitude / longitude; great circles; time zones; development; trade; migration of labour
- Gapminder Tools https://www.gapminder.org/tools/#$chart-type=bubbles&url=v1
- Engaging Data (https://engaging-data.com/assembling-world/) to teach development e.g. (https://twitter.com/mildthing99/status/1122806454107373568) and development (https://twitter.com/mildthing99/status/11228063333408153

- Global Forest watch https://www.globalforestwatch.org
- Google Public Data Explorer https://www.google.com/publicdata/directory?hl=en_US&dl=en_US#!
- Panoply (NASA) http://www.giss.nasa.gov/tools/panoply/
- USGS. World earthquakes live https://earthquake.usgs.gov/earthquakes/map/
- World Bank http://maps.worldbank.org/p2e/mcmap/map.html
- World Database on Protected Areas (WDPA) https://www.protectedplanet.net/
- World Trade Organization https://www.wto.org/english/res_e/statis_e/statis_bis_e.htm?solution=WTO&path=/Dashboards/MAPS&file=Map.wcdf&bookmarkState=%257B%2522impl%2522:%2522client%2522,%2522params%2522:%257B%2522langParam%2522:%2522es%2522%257D%257D

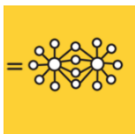
14.2 Practical recommendations from the literature review

As part of the project work we did a serious literature review. This resulted in an extensive document, which can be found on the GI-Pedagogy website. These are some of the practical recommendations:

- Adapt practice by increasing the challenge of questions and providing new contexts for pupils to apply their skills (Stringer et al., 2019).
- Give support for retrieval practice and self-quizzing to increase retention of ideas and knowledge (Stringer et al., 2019).
- Use web maps and their analysis, Web-based GIS and create web map applications (Kerski and Baker, 2019).
- Use geotechnologies to improve the capacity to handle geographic information as a part of their digital culture (Sanchez, 2009).
- Use visuals correctly for communicating complex ideas in an efficient way, leaving more cognitive resources free to engage in higher order thinking (Caglioli, 2018).
- Compile ArcGIS materials suitable for national conditions and student characteristics and provide supporting materials for teachers, and set up relevant websites (Wu, 2018).
- Collect data using collaborative mapping tools based on citizen contributions, to allow mapping real-time data (Kerski and Baker, 2019).
- Look at the impact of the pedagogy and approach, as well as the subject being taught and the specifics of the school context (Stringer et al., 2019).

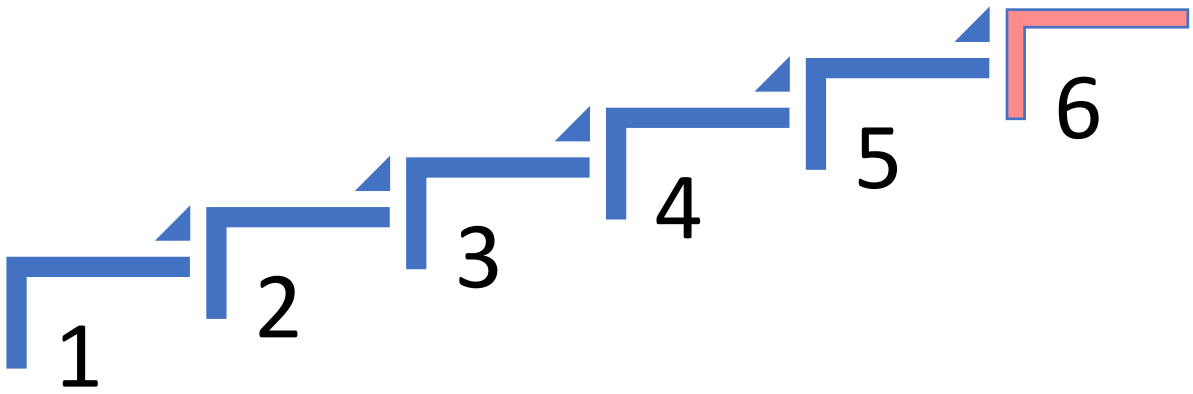
CASE STUDY TEMPLATE

Rosenshine's Principles (dual coding icons) for teachers' use

Principle	Description	Icon
1	**Rosenshine 1 – (Daily) review** Start each lesson with a repetition of previous material. Regular repetition reinforces what was learned and leads to more spontaneous recall.	
2	**Rosenshine 2 - New materials in small steps** Present learning materials in small amounts. Accompany students with practice after each step.	
3	**Rosenshine 3 - Ask questions (onderwijsleergesprek)** They connect the new learning material with previous knowledge and practise it.	
4	**Rosenshine 4 - Provide models** Pupils can focus on the steps to solve a problem.	
5	**Rosenshine 5 - Guide student practice** The best teachers spend a lot of time supervising the practice/learning of new material.	

6	**Rosenshine 6 - Check student understanding (onderwijsleergesprek)** By checking in between, pupils can learn the material with fewer mistakes.	
7	**Rosenshine 7 - Obtain high success rate** Aim for the students to experience approximately 80% success in the exercises, questioning ...	
8	**Rosenshine 8 - Scaffolds for difficult tasks** The teacher provides temporary support that decreases as students become more competent.	
9	**Rosenshine 9 - Independent practice** Provide practice time in and out of the classroom so that the learned material can be automated.	
10	**Rosenshine 10 – (Weekly and monthly) review** Pupils need to practise intensively in order to automate the material. Not necessary for this key study.	

Icons based on [Rosenshine poster by Oliver Caviglioli](#) and used with permission



Step 1: Direct instruction / teacher facilitated stage - this is where schema building begins. Present new material.

Step 2: Modelling / Scaffolding, with review and questioning – what data are needed?

Step 3: Individual exploration

Step 4: Review - discussion

Step 5: Problem-solving

Step 6: Presentation/Assessment (Peer assessment possible too) and sharing of outcomes. This will also be the stage where students may feel secure enough to start their own exploration.

= checking understanding

CASE STUDY: ADD HERE

Step	***Identify a topic / story that is going to be told / explored using GIS***	**Other**
	[LESSON TITLE]	
	[LESSON SUBTITLE]	
	Curriculum context:	
	Target age group:	
LOs	***Learning objectives***	
	[Ideas for Learning objective statements] • Retrieve prior learning about… • Describe and explain links between… • Describe, explain and evaluate… Can link to SDGs especially: (Choose only those related to the vignette topic and activities) 	

		
Res	**Key resources and embedded hyperlinks if appropriate**	
	e.g. GIS resource; .pptx .csv .doc; video or audio clips [Thumbnails, if available e.g. for GIS resource(s)]	
	Individual exploration: [RESOURCES for students e.g. .pptx .csv .doc; video or audio clips]	
	Learning phases (may be one lesson or a sequence of lessons)	**Timing**
0	***Step 0: Retrieval (e.g. quiz to check prior learning)***	**min**
	Review Retrieval of prior learning about … Could be a 'Do Now' task or quiz.	
	Check student understanding / misconceptions about … Are schema in place?	
1	***Step 1: Direct instruction / teacher facilitated - schema building begins***	**min**
	New material in small steps **Key question(s) and/or concept(s):** [BRIEF DETAILS] > Refer to this explicitly as a GIS resource and, if necessary, explain / remind students about what GIS is and how it works etc.	

	Input in small steps using GIS layers to **build the narrative**. • Step • Step • Step	
	**Ask questions (klasleergesprek):** Are schema in place? • Key question(s) to check student understanding… • Invite student suggestions (e.g. think-pair-share).	
	Input in small steps using GIS layers to **continue to build the narrative**. • Step • Step • Step	
2	***Step 2: Modelling / Scaffolding Review and Questioning – what data are needed?***	**min**
	**Modelling**	
	Modelling of individual exploration task (see ***Step 3***) [RESOURCES providing models for students e.g. .pptx .csv .doc; video or audio clips]	
	**Scaffolding**	
	e.g. guidelines; teacher support; peer support [RESOURCES providing models for students e.g. .pptx .csv .doc; video or audio clips]	
	**Obtain high success rate** Instructions in ppt; Teacher and peer support	
3	***Step 3: Individual exploration***	**min**
	**Guide student practice**	
	**Obtain high success rate**	
	Instructions in ppt; Teacher and peer support [RESOURCES so to support students e.g. .pptx .csv .doc; video or audio clips]	

4	***Step 4: Review - discussion***	**min**
	**Check student understanding (onderwijsleergesprek):** Are schema in place?	
	Review of ***Step 3: Individual exploration*** • Feedback from students about their findings. Corrections discussed.	
5	***Step 5: Problem-solving***	**min**
	**Independent practice** Deliberate practice	
	Anomalies resource prompt discussion: Q+A to check and deepen student understanding	
6	***Step 6: Presentation/Assessment (incl peer assessment) sharing of outcomes.***	**min**
	**Check student understanding (onderwijsleergesprek):** Are schema in place? • Key question(s) to check student understanding… • Invite student suggestions (e.g. think-pair-share).	
	Review of ***Step B3: Individual exploration*** [EXAMPLES… • Feedback from students about their findings. Corrections discussed. • Students present findings • Teacher and peer evaluation]	
	Link to next steps in learning	

This toolkit was developed by the GIPedagogy partners.