A TEACHING MODEL TO RAISE AWARENESS OF SUSTAINABILITY USING GEOINFORMATION

UN MODELO DOCENTE PARA SENSIBILIZAR SOBRE LA SOSTENIBILIDAD EMPLEANDO LA GEOINFORMACIÓN

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Abstract

The increase in geoinformation and its integrated use in cloud-based geographic information systems, or Web GIS, facilitates visualization of data and helps to improve our understanding of socio-economic factors as well as the natural landscape. Effective application of these tools in the classroom requires a change in teachers' pedagogies. Thus, a review of existing pedagogies and a brief questionnaire given to teachers with lots of experience of using Web GIS, was carried out in order to identify how they were integrating online interactive maps into their teaching to make learning more effective. The results led to the development of a series of learning scenarios, or vignettes. These all use the visualization provided by online maps, to encourage more critical and reasoned learning. They also contribute to educating for sustainability, as they highlight trends and interrelationships that are intended to promote transformative action, beyond the theoretical knowledge and

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application of the Sustainable Development Goals. Direct observation in teacher training classrooms and detailed discussion over each result obtained has validated a teaching model. To support the use of these materials and the application of the model, a training course has been designed for teachers who are new to the profession or those who are interested in integrating these tools into their teaching. To date, trainee teachers who have been introduced to the model have expressed their satisfaction with this new way of working in secondary classrooms.

Keywords

Geography; Geographic Information Systems; Sustainable Development Goals; Vignette; Geoinformation.

Resumen

El incremento de la geoinformación y su integración en los sistemas de información geográfica en la nube o SIG Web, facilitan la visualización de los datos y una mejora de la comprensión de la realidad socioeconómica y territorial del paisaje. La efectividad de estas herramientas en las aulas hace necesario un cambio en las pedagogías de los docentes. Así, se ha realizado un seguimiento de las pedagogías existentes y un pequeño cuestionario a profesores experimentados en el empleo de SIG Web con la finalidad de formular cómo integrar los mapas interactivos en línea en la docencia para un aprendizaje más eficiente y elaborar con estos resultados una serie de situaciones de aprendizaje o *vignettes*. En todas ellas se emplean mapas en línea cuya visualización fomenta el aprendizaje crítico y razonado. Con ellos también se colabora en educar para la sostenibilidad, ya que evidencian tendencias e interrelaciones que se pretende promuevan una acción transformadora, más allá del conocimiento y aplicación teórica de los Objetivos de Desarrollo Sostenible. La observación directa en las aulas de formación del profesorado y una detallada discusión sobre cada resultado que se va obteniendo han validado el modelo docente creado. Para apoyar el empleo de estos materiales y la aplicación del modelo se ha diseñado un curso de formación para el profesorado que se inicia en la profesión o aquél otro con interés en integrar estas herramientas en su docencia. Hasta el momento los profesores en formación que han conocido este modelo han mostrado su satisfacción, su satisfacción por esta nueva forma de trabajar en las aulas de secundaria.

Palabras clave

Geografía; Sistemas de Información Geográfica; Objetivos de Desarrollo Sostenible; Vignette; Geoinformación.

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1. INTRODUCTION

The revolution in geographic information and cloud-based computing has enabled new classroom learning methodologies. Geospatial skills can be improved by using online web mapping. There are two essential pillars for this: development or use of the mapping itself, and critical reflection. In this way, geodata displayed on web maps allows us to obtain new insights and learning.

The increasing amount of freely-available geoinformation (GI) and requirements of official *curricula* highlight the need to integrate geotechnologies into secondary school teaching. Thus, it is essential to train 'experienced' teachers and early career teachers, such as trainees, master's degree students in secondary education, teacher educators, and all those who are interested in teaching and learning to use GIS technologies in an innovative pedagogical way to support Powerful Geographical Thinking (PGT) and meet the needs of the Sustainable Development Goals (SDGs). The increase in GI and the growing ease of its use in cloud-based geographic information systems, or Web GIS, to visualize data and improve understanding of socio-economic and territorial reality requires a change in teachers' pedagogies.

An innovative pedagogy has been specifically applied to national *curricula* by our GI-Pedagogy project team to identify how to take advantage of the exciting and innovative world of open data and open science. The GI-Pedagogy team also identified relevant data sources in order to help connect schools with the real world and raise pupils' citizenship awareness. The use of data and the essential nature of GIS in all aspects of our daily lives are also demonstrated. Thus, we aim to draw on and transform existing available knowledge, materials, concepts, and ideas to train new and early career teachers, and further the professional development of more 'experienced' teachers.

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 and presented as layers on top of a base map. Symbols can be used to identify patterns in the data, and spatial tools offer other options for collecting and displaying the data. Thus, teachers should aim to use the opportunities that GIS provides to analyse real world data from a wide number of sources.

GIS is a powerful tool that can be used to investigate and explore the world, but it needs further work to demonstrate its usefulness, in the same way as other Information and Communication Technology (ICT) tools (Stringer et al., 2019). ESRI has made their ArcGIS Online family of apps, such as Survey123, Field Maps or StoryMaps, available free to all schools in EU countries (and further afield) so it is possible to access them easily. GIS should not just be 'something else to teach', as it enables clearer instruction about subject content, and has the potential to make teaching more effective. GIS needs to be embedded across the *curriculum*, and across subject teaching, and must be introduced to students in a stepped process, to

avoid cognitive overload (Sweller et al., 2019). Without regular opportunities to use GIS, students will be introduced to it in occasional lessons, but are likely to forget about it within a short time. Periodic review, and the steady acquisition of blocks of learning (schema) are important. All these questions link with pedagogy. GIS is not just for professionals in business, but for all young people to have experience with. It improves critical spatial thinking (Bearman et al., 2016; Kim & Bednarz, 2013) and makes it possible to advance the TPACK model adding other dimensions, such as sustainability or affectivity and emotions (Puertas et al., 2021). This allows for changes in attitudes to territory, and for 'extension work' to deal with sustainability issues and values (Álvarez, 2020).

Doering et al. (2009) enhance the teaching, use and implementation of geospatial technologies beyond the TPACK model, by emphasising that teachers should develop geographical technological pedagogical content knowledge (G-TPACK). The focus changes from what teachers should know to effectively integrating technology in their classrooms to study how their geographical knowledge should be used to support their teaching in the most effective way. The lack of development of pedagogical models for teaching geospatial technologies appears to have been one main reason why they have not been incorporated into lessons. Doering et al.'s (2009) model, known as GeoThentic, trains teachers in a very interactive and collaborative way using an online problem-based course: to develop their technological knowledge using geospatial technologies; their pedagogical knowledge by investigating optimal pedagogy for geographic problem-solving with geospatial technologies; and their content knowledge by developing the specific geographical content area needed to effectively teach the problem-solving modules.

It is important to emphasize that educating for sustainability is not simply an 'add-on' to existing structures and *curricula*, but implies a change based on the ability to respond to the current crisis and take advantage of opportunities (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 (1983) 'multiple intelligences', after the linguistic-verbal, musical, logical-mathematical, bodily-kinesthetic, interpersonal, intrapersonal, and naturalistic intelligences were defined). Specifically, 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 in turn 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, by adapting the TPACK model (Figure 1).

The principal differences between GI-Pedagogy and other GIS-related projects are the particular focus on pedagogy (the methods and practice of teaching) and the use of evidence-based approaches.

Thus, the main objective of this project is to design a teaching model that ensures efficient learning using geoinformation and ArcGIS Online that is informed by pedagogic research. By researching innovative methods for teaching with GIS, the
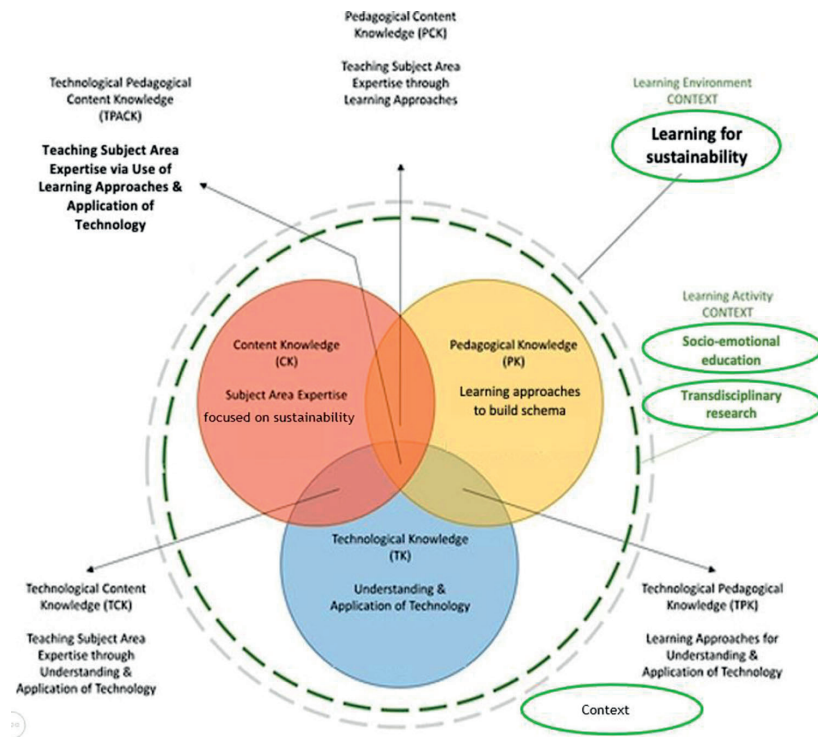
FIGURE 1. ADJUSTED TPACK MODEL BASED ON RICKLES ET AL., 2017, P.16, MIRSHA, 2019 AND PUERTAS ET AL., 2021

aim of this study is to provide teachers with the skills and resources they need to embed the use of digital mapping into their everyday geography teaching. This is done by drawing on Rosenshine's Principles of Instruction and the findings from cognitive science to design a framework for teachers to support their use of GIS in their lessons. By using a series of steps, it provides teachers with the pedagogical basis for teaching with GIS in a well sequenced and integrated way. This approach seeks to support new trainees and early career teachers by drawing on best practice ideas and by focusing on the 'P' in the well-known TPACK model: the pedagogy. This involves identifying opportunities to teach with GIS as an integrated part of an existing *curriculum* by drawing on examples of next practice as part of the lessons, rather than using GIS as an additional tool. In this way these provide busy teachers with ways to use GIS to make learning better than it would have been without using GIS. This framework, therefore provides suitable help to plan lessons which use GIS effectively to teach with. This has then been used to develop examples for its use demonstrated with a number of suggested case-studies, for teachers to use in the classroom. These have been designed as a starting point for practitioners to further develop themselves to support their own teaching with GIS. In this way they can start to use these steps as a practical tool to help them to embed GIS in their lessons routinely. By creating a rubric for this, GI-Pedagogy allows allows teachers to assess the case-studies developed, and then go on to create their own vignettes using this pedagogic framework.

In order to develop these case-studies or vignettes, GI-Pedagogy involves using the pedagogic framework developed by the project, to select relevant content supported by web references and key questions which are interwoven to allow learners to deepen their understanding of a topic or issue, through hypothesis–testing and problem–solving. Vignettes are thematically oriented, and may include simulations and predictions supported by knowledge. They integrate the teacher and learner's perspective (Chaloupka et al., 1998) and are a way of assessing motivation, evidence of problem-solving and critical thinking (Jeffries et al., 2005). Key questions include asking if vignettes could be a tool for assessing teachers' pedagogical understanding? Are they able to help raise teachers' awareness of the need for students to understand and learn what is being explained in class?

The results address these questions and help develop a teacher-training course that fully incorporates web-based mapping software into the geography *curriculum*. First, however, the methodology will be outlined.

2. METHOD

This project began by reviewing and distilling the conclusions from over 120 relevant research papers, including those on cognitive science and GIS.

In the process, the development of schema was explored as well as modelling linked to Rosenshine's Principles (Sherrington, 2019) derived from cognitive science research-based evidence on how the brain acquires and uses information. This drew on the findings from Rosenshine's work which came from three separate sources of research: cognitive science and how the brain works, observations of teachers whose students saw the highest improvement in assessment marks, and an analysis of instructional methods (Donert et al., 2000). From this, Rosenshine developed his Principles of Instruction, which advocate the breaking down of material into steps of information and learning that is built up over a period of time, through sequencing and modelling, making use of questions, and giving sufficient time to fully integrate them into the learning. Rosenshine (2012) recommends that experiential activities should always be employed, and that students are taken through a series of steps that allow them to learn how to use GIS at their own pace. At each stage, we will explore how GIS can improve overall understanding of both itself and the real world. We shall also identify effective strategies for engaging learners on a journey that always offers something new to learn, as it has no definitive end.

Next, a small-scale qualitative survey was carried out to support the research findings of a group of 22 teachers who were identified or self-identified as being 'expert users of web GIS or interactive online maps', to find out about their use of GIS. Questions covered four key areas. Respondents were asked to identify the context for their use of GIS, what it was used to teach, how and why they used it and how effective they thought the learning was. These responses were then used to help to develop our model, and led to the creation of a series of case-studies using a template to explore the use of our model in the classroom, and

make any suitable adjustments. In this way, the rubric created, helps to support the effectiveness of the learning.

Finally, a training course was run to help teachers who were interested in GIS technologies to support Powerful Geographical Thinking, and also meet the needs of the Sustainable Development Goals. This model has also been used in teacher training courses the authors are involved in.

3. RESULTS

The results created, piloted and evaluated are presented here as a set of steps, followed by the learning model for teachers, the vignette template case study, and finally, the training course to disseminate. However, we begin by reviewing the relevant literature and our survey.

3.1. SMALL SURVEY RESULTS

As shown from the results of the small-scale survey of teachers, led by Wilson (2020), the respondents were all regular users of GIS (41% weekly and 27 % at least twice each term) with the majority having more than 10 years' experience, and only 4 recorded as having less than 6 years. The respondents came from a variety of countries including: Austria (4%), Belgium (36%), Romania (5%), Spain (23%), Switzerland (5%) and the United Kingdom (27%). It was interesting to see that the majority used ArcGIS Online, with only some using Google Earth, and Digimap for Schools (a subscription service for UK schools) and just one teacher using QGIS. From the survey results, there were a variety of different uses of GIS demonstrated, which appeared to be more focused on the *curriculum* knowledge for UK respondents, compared with other European Teachers whose use on average was found to focus more on developing students' skills of using GIS to think critically and support problem solving. Despite this difference, overall it was clear that respondents felt that it was important for GIS to be taught using clear instructions, either using a worksheet or video, so that tasks could be modelled, and then further supported with both formal and informal guidance afterwards; by sharing ideas and discussions, and from the teacher's perspective, by offering technical support to students, as needed. Respondents felt it was useful to provide clear instructions in both physical and virtual settings. Teachers also mentioned the absence of fieldwork that focuses on physical geography, which may well have been because of the pandemic and an increasing use of GIS among students more generally. In this context, and in order to integrate GIS into the teaching *curriculum*, those interviewed made a series of suggestions. First, that the promotion of GIS use in the classroom might also be seen as a way to aid teachers' learning. Secondly, in terms of enquiry-based student education, they proposed the use of GIS tools to support research-based learning resources (such as WebQuest), including structured tasks and story maps. Thirdly, teachers suggested

that manuals to support spatial literacy skills and independent discovery to explore and create story maps might also be very useful. Finally, they recommended using written instructions with a 'technical focus' to act as a tool to support learning critical and spatial thinking skills.

So how effective is the learning using GIS? If these suggestions from the survey are to be taken on board, GIS needs to become part of every educator's personal teaching toolkit. Students need to learn with and about GIS because it is now essential for business. 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 technical knowledge to proceed very far without guidance. The use of GIS for direct instruction is a useful way of modelling the use of this technology to students, as a way of exploring problem-solving techniques, and is explored further below.

3.2. THE IMPORTANCE THE SUSTAINABLE DEVELOPMENT GOALS

Geography is an important subject for developing a better understanding of our current world. Its study is therefore crucial for helping to work towards meeting the Sustainable Development Goals. In order to do this, it requires students to develop skills such as critical analysis, to enable a systematic reflection on the interrelationships between territory, landscape and society, in both the real and virtual worlds. In this way it helps students to become more informed and responsible citizens capable of adopting a more sustainable lifestyle which advocates the ability to make reflective, knowledgeable and collaborative decisions (Murga-Menoyo, 2015). In this way, education for the SDGs must ensure that all students acquire the theoretical and practical knowledge necessary to promote sustainable development and adopt sustainable lifestyles. Education therefore needs to focus on the development of the whole person, as an integrated respectful member of the earth's global environment, as part of an eco-dependent community willing to take the moral responsibility for life on our planet (Murga-Menoyo, 2020).

In this sense, public policies to integrate Education for Sustainable Development (ESD) into all formal, non-formal and informal learning contexts are a key factor. The *curriculum* can therefore be seen as an effective vehicle for change in all educational settings, and so an important part of teacher training. It is therefore essential to ensure that the SDGs are integrated into *curriculum* and national quality standards, so that they are supported with suitable indicators which are able to measure outcomes that reflect this, in addition to the need for universities to also work towards this. Integrating Education for Sustainable Development (ESD) into competencies, teacher standards, certification and accreditation of teachers and teacher education institutions would encourage their implementation in the classroom. Appropriate pedagogical approaches must be learner-centred, action-oriented and transformative. It is therefore vital not only to include SDG-related

content in *curricula*, but also to use transformative, action-oriented pedagogies (Murga-Menoyo, 2021). This process of educating for sustainable development is known as curricular sustainability.

3.3. REVIEWING EXISTING PEDAGOGIES AND THE SMALL-SCALE RESEARCH SURVEY

Barak Rosenshine's (2012) 10 principles were not GIS specific, but he pioneered an innovative approach that considered pedagogical intent and made it possible to check students' understanding. In our project we sought to identify how these principles could be applied to GIS teaching, as GIS needs to be embedded in everyday activities if teachers and students are to gain the automaticity that emerges from learning, repetition and practice. The aim is not for teachers to become GIS experts; rather our experience tells us that it is better to ask lots of questions and interact with students at each stage in order to check their understanding. 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 their *curriculum* development. Teachers need to make decisions about how best to achieve the work within the given time constraints, to meet the particular needs of their students.

Tom Sherrington (2019) explored the idea of combining the principles of Rosenshine into four main strands to provide a possible workflow for teachers, which was later used by Sophie Wilson (Figure 2). This does not involve merging the principles but recognizing that they complement each other. This is not a checklist, but a framework for introducing new knowledge.
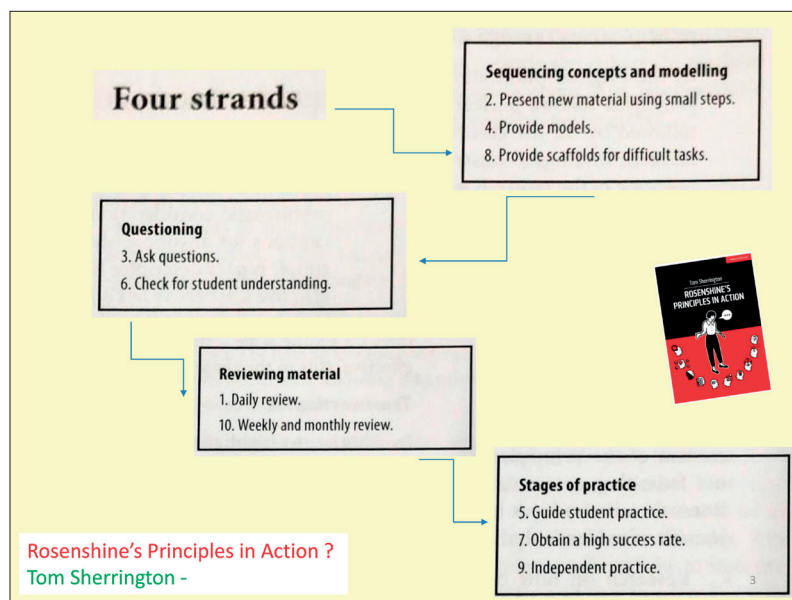

FIGURE 2. SOPHIE WILSON AFTER SHERRINGTON (2020)

When Rosenshine talks about reviewing material (and student progress), we consider this in terms of GIS skills and knowledge as well as linked subject content. 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, to facilitate their learning.

In this context, any GIS task needs to be modelled first, using a series of steps through which students and teachers work to develop their understanding. Videos can be used to introduce students to the various stages, which are similar to some of the blended learning approaches being adopted as a result of the COVID-19 pandemic such as flipped teaching, the use of MOOCs. It is easy to get lost in the technical and practical aspects of using a GIS tool, and it can take a lot of time to unpick a task. Therefore, these steps need to be carefully considered when planning a lesson sequence, and teachers need to be confident enough to complete them in front of a class. Sweller et al. (2019) uses the phrase "scaffolded freedom" to reflect the careful use of support that may be useful at different stages for groups or individuals, as required, and as competency increases. Our model addresses all the aforementioned issues.

Teachers also need to develop agency in their use of technology by building their own confidence. Thus, GIS needs to become part of the 'furniture' in classrooms and lecture halls. Maps are often used, but – rather than using paper maps, it would be better if Google Earth or digital atlases were used – so that GIS provide students with interactive digital maps. Specific examples of GI(S) apps / websites / tools highlighted in our research included ArcGIS Online (AGOL), which is a free platform available to most schools in the EU. More advanced GIS analysis can be undertaken with ArcGIS Pro. Another option is the Google Earth suite and the new 'Projects' option, which can be used to create tours (e.g., those of Andy Funnell: *https://earthcasestudies.wordpress.com/*); Google Earth Studio, which creates stories similar in style to StoryMaps, with aerial views and video facilities, and; Google Earth Pro, which improves Google Earth functionality. Tools for fieldwork data acquisition - such as ESRI Survey123 and Field Maps, ONA, ODK collect or QField collector linking to QGIS family– are recommended for more advanced classes.

GIS is the perfect vehicle for teaching and achieving 'powerful knowledge' (Young et al. 2013) and applying cognitive science in projects such as GeoCapabilities project (Solem et al, 2013; Biddulph et al., 2020) which has explored the development of such knowledge within geography or GI-Learner (Donert et al., 2016; Zwartjes et al., 2017; Zwartjes and De Lázaro, 2019).

If students use GIS frequently, they will learn more rapidly, as knowledge needs to be employed regularly for it to become part of the long-term memory. When teaching with GIS, teachers need to do so explicitly, to make students aware of it, and constantly monitor students use of GIS and suggest further ideas. This is what we might call "powerful pedagogy": pedagogy that leads to critical thinking (Bearman, 2016; Biddulph et al., 2020; Kim and Bednarz, 2013) and better decision-making, by focusing on the acquisition of powerful GIS skills and knowledge.

In order to benefit from these tools, students need to be given time, to understand the purpose of GIS before they start to produce their own maps, to ensure they are of a high quality and use the tool's full potential. This might include considering the way that data is best visualized can be done without undertaking deep analysis. This is technically still "creating a map", but ideally students will move on to a point where they can make use of GIS to create their own maps using appropriate symbology and analytical tools.

Having acquired the required skills and knowledge to use GIS, agency needs to be passed to the learner. Known as geo-literacy, the aim is to guide teachers and students towards becoming increasingly fluent in their use of mapping and geographical information.

Questioning and addressing misconceptions are vital to the success of this way of learning. It can therefore be concluded that cloud-based computing and GIS use is becoming an essential tool for 21st century classrooms.

3.4. THE LEARNING MODEL FOR TEACHERS

The GI-Pedagogy model aims to bridge the gap between early adopters who are confident with the technology, and those who have never used GIS before and are looking to start. Although Rosenshine's principles are not a model, they can be used, together with cognitive science, as a basis to create a series of structured steps. These steps – which might be whole lessons, or activities within lessons help develop a student's 'schema' by making links between their learning. In this way, generative learning integrates the use of GIS by connecting new knowledge with existing schema.

This approach provides a scaffold for teachers and students, avoids cognitive overload, by enabling new material to move into the long-term memory using schema, and ensures the whole process is effective. Before specifying the steps in terms of GIS it is worth recalling Tom Sherrington's (2019) 'key elements' that 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 information at any one time.
* The long-term memory is an essential part of our prior and future learning, as we process information it links to our schema which is stored in our long-term memory.
* We retrieve relevant information from our long-term memory and employ it in our working memory when it is needed.
* We organize all this information into schema by building up links with our long-term memory. New information typically only becomes stored if we can connect it to knowledge we already have; therefore, our 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 organize new information, as it relates to our existing schema, and we start to retrieve it more readily.
✳ We will forget information that we don't store successfully in a meaningful schema when we are first introduced to it, or if we don't retrieve it frequently enough.
✳ If a schema contains incorrect information, we can't simply 'overwrite' it, but need to unpick and fully re-learn it to correct the schema. The teacher is still required here.

These elements will now be incorporated into our specific GIS steps (Figure 3). As teachers begin to imagine learners ascending these steps, they may also become more critical of existing resources, which will help them in selecting and developing materials for use in their own classrooms. An important part of GIS is that it helps develop a narrative, which is employed by the teacher when introducing a particular topic. Stories are powerful, and our model is based on narrative construction. How can GIS be successfully integrated into lessons? Of course, the motivation to take the first step is the desire to learn how to teach with GIS, in a way that makes learning better and more effective.
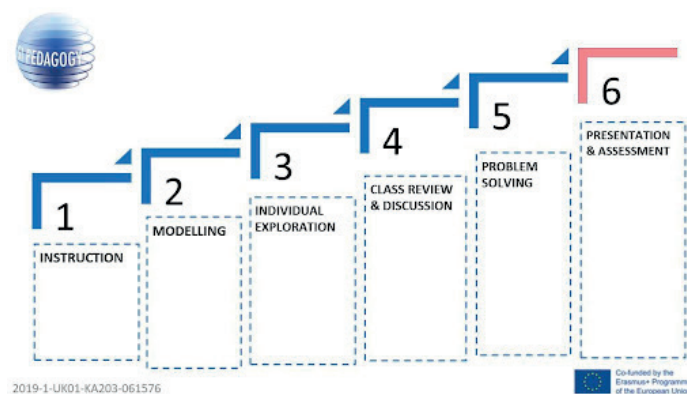

FIGURE 3. THE STEPS OF THE DEVELOPED GI-PEDAGOGY MODEL

The aim is to move between the steps both up and down, but not necessarily starting from the first one, depending on the complexity of the use of GIS. With each step there is an increase in complexity in the use of GIS, and it is possible to 'step down' and revisit previous ones. In this way teachers are able to explore alternative approaches and build up the use of GIS in their teaching, so this becomes increasingly fluent and integrated into lessons which make learning better as a consequence.

The entire step model can be represented in a diagram. 'Step 0', before we even start climbing, might involve a check on prior learning, but this is not depicted in the diagram. The five steps leading to the potential for a sixth one - which could take the form of either a student presentation or some sort of assessment – these are best represented in the lesson plan using questions.

Step 1: Direct instruction / teacher-facilitated stage. This is where 'schema-building' begins. New material is presented.

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

Step 3: Individual exploration

Step 4: Class review and discussion

Step 5: Problem-solving

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

The little symbol of the small ramp between each step represents the opportunity to check for understanding by moving between the steps in both directions. Steps can be skipped by groups who may have already acquired schema or may be visited several times during a lesson sequence. The steps are not intended to end at number 6.

In order to help sequence the learning, a cube has been used to present a suitable framework for teachers to use to identify the prior and future learning to put the new learning into context. In this way it is possible to deconstruct the learning into suitable chunks by noting key learning points, to ensure that new content is introduced in a way that is mindful of its context. In this way, the cube helps to support the development of the learners' schema, in a way that avoids overloading the working memory (Figure 4).
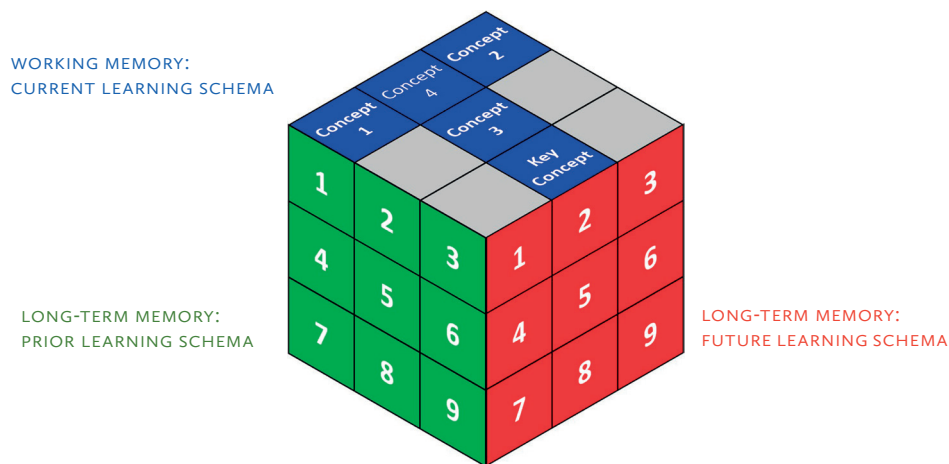

FIGURA 4. CUBE CONCEPTS:
1. BLUE TABLE - WORKING MEMORY: CURRENT LEARNING SCHEMA
WRITE UP TO FIVE KEY IDEAS FOR THE LESSON. AS WELL AS THE MAIN CONCEPT, ADD THREE OR FOUR OTHER KEY IDEAS THAT WILL BUILD TOWARDS THE MAIN CONCEPT. IF YOU ARE NOT USING A 4TH ADDITIONAL CONCEPT, THEN LEAVE THE ROW THAT STARTS WITH '4' BLANK
2. GREEN TABLE - LONG-TERM MEMORY: PRIOR LEARNING SCHEMA
ADD UP TO NINE ITEMS FROM PRIOR LEARNING THAT SHOULD ALREADY BE PART OF THE SCHEMA IN STUDENTS' LONG-TERM MEMORY
3. RED TABLE - LONG-TERM MEMORY: FUTURE LEARNING SCHEMA
ADD UP TO NINE ITEMS THAT WILL BE TAUGHT IN THE FUTURE THAT WILL BECOME PART OF THE SCHEMA IN STUDENTS' LONG-TERM MEMORY

At the end of the case-study or vignette, the main concepts should be correctly defined by using several sources to define in a maximum of 5-6 lines. A definition serves to clearly delimit the thematic, temporal and territorial scope of a concept. The concept can be enriched, if appropriate, with the why and the how, and relate it to other elements, behavioural patterns… One or two examples and a significant image, graph or map should be added; but always without using the defined word as part of the definition.

To assist in thinking around the model, a 'toolkit' and a 'blank template' have been developed by experienced teachers to provide some working examples in the form of study-cases or vignettes. These are available on the website: *https://www.gilearner.ugent.be/gi-pedagogy/*.

3.5. VIGNETTES AND THE RUBRIC TO ASSESS

The list of vignettes created to date are shown in Table 1.

TABLE 1. VIGNETTES CREATED

Level	Main target age group (in years)	Author	Title	Map topic	URL GIS Maps
K7-12	11 to 17	S. Wilson	Physical Geography	Mountains, rivers, ecosystems, landcover, HDI and world cities.	*https://arcg.is/1CnqDG0*
K7-9	11 to 14	A. Parkinson	Water security	Water security / Water consumption by country	*https://arcg.is/Pa4Ge*
K7-9	11 to 14	B. Conway	Demographic transition model (DTM). Geographical distribution of DTM stages.	Demographic Transition Model (DTM)	*https://arcg.is/1jfzrP*
K8-10	13 to 16	B. Conway	Economic sectors and the Clark Fisher Model	Journey of a product: A loaf of bread	*https://arcg.is/Kmejq*
K9	14 to 15	M.L. de Lázaro	Globalization	World Bank-Gross National Income. World transport.	*https://arcg.is/1DKXu5*
K9-11	14 to 16	M. Lindner- Fally	Migration	Global Net Migration	*https://arcg.is/0H4TyW*
K9-10	14 to 16	B. Conway	Tectonic plate margins	Tectonic plate motion	*https://arcg.is/0vC4e4*
K9-12	14 to 17	D. Prodan	Biodiversity	Biomes in the World	*https://arcg.is/199H88*
K10	15 to 16	M.A. Puertas	Geopolitics in today's world	Geopolitics	*https://arcg.is/1v9O44*
K10-12	15 to 18	B. Conway	Urbanization - Draft GI-Learner deconstruction	Central London	*https://arcg.is/1uDvKu*
K11	16 to 17	L. Zwartjes	Sea Level rise	Economic impact of sea level rise	*https://arcg.is/15L5XS0*
K11-12	16 to 18	M.L. de Lázaro	Economic inequalities in the world	Economic inequalities	*https://arcg.is/1qinaS*
K11-12	17 to 18	L. Zwartjes	Wind energy	Wind energy	*https://arcg.is/1zqLrX0*

Following this teaching experience and in order to facilitate the evaluation on lesson plans (or those created in the future), a rubric has been established in order to establish the quality of the vignettes (Table 2).

TABLE 2. RUBRIC GRADES TO AID ASSESSMENT

Indicators of achievement	Excellent (1)	Quite acceptable (Very good) (0.75)	Moderately acceptable (Good) (0.5)	Partially done (Poor) (0.25)	Not done (Fail) (0)
	The case study fully addresses all relevant aspects of the items. Any shortcoming is minor.	The case study addresses the question very well, although improvements are still possible.	The case study addresses the question well, but improvements are necessary.	The case study broadly addresses the question, but there are significant weaknesses.	The case study fails on the information required.
1. Adequacy of the chosen title (the title provides a good description of the content) and is within the current *curricula*					
2. Provides key information on the development and implementation of the vignette					
3. Contains some activity with the detail required in the quality standards. (Use of contemporary data. Variety and quality of the resources used).					
4. Explanatory coherence of discourse, clarity of ideas and argumentation. Focuses the topic on student learning. (It is understandable).					
5. Correct application of the concepts in the vignette. (The key concepts explained in the vignette are clear, scientifically rigorous in citing sources, adaption to current legislation...).					
6. It encourages critical thinking. Suggests new questions and reflections that open doors to subsequent debates.					
7. Leverages geo-technologies, especially cloud-based GIS, for learning and teaching aims.					

8. Content, spelling and grammatical expressions are correct.					
9. In relation to education for the Sustainable Development Goals (SDGs): -Have you made any references on how to educate about SDGs by providing specific steps to achieve any of the sustainability competences? Have the following competences on sustainability been achieved: a) Critical analysis (e.g. using the same data in maps with different intervals; b) Systemic reflection; c) Responsibility for future generations; d) Ability to make decisions collaboratively? -Have activities been proposed to assess progress in learning on the SDGs? See UNESCO document for a further knowledge: *https://unstats.un.org/sdgs/indicators/Global%20Indicator%20Framework%20after%20 2022%20refinement_Eng.pdf*					
10. Meets the standard of work requested (template / Rosenshine principals)					
Total					

3.6. TEACHER TRAINING COURSE

On the basis of the above research outcomes, a five-part teacher-training course has been developed and is due to be launched soon. The first part introduces the topic, and responds to the questions: what is GIS and how is it used?; why is GIS a valuable tool for teaching? and what is needed to use GIS in the teaching process? The second part explains the innovative pedagogy, and how it is based on research results and practice. The third section seeks to integrate the model using vignettes in the framework of the secondary school *curriculum*, based on physical and human geography. The fourth deconstructs the model to explain two case studies; while the last part, called 'I, we, you', demonstrates why it is necessary to give teachers knowledge to create their own vignettes. The teacher training course will be accessible

to all qualified teachers who have an interest in GIS. It will be shaped in a MOOC format.

4. CONCLUSIONS

The GI-Pedagogy research team has created a model that explores the benefits and barriers to using GIS in secondary school classrooms after researching teaching practice in secondary and higher education. The proposed model also suggests how to overcome obstacles in using it. The structure of the model is as simple as possible, and is supported by research evidence.

It is also worth noting 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 a classroom and doesn't necessarily require an ICT suite.

In summary, the case-studies or vignettes provided by the research team and direct observation of the teacher training lessons has proved that the model works.

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