QTIMaps: A Model to Enable Web Maps in Assessment

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ABSTRACT

Test-based e-Assessment approaches are mostly focused on the assessment of knowledge and not on that of other skills, which could be supported by multimedia interactive services. This paper presents the QTIMaps model, which combines the IMS QTI standard with web maps services enabling the computational assessment of geographical skills. We introduce a reference implementation of the model, with Google Maps as the web map service, comprising both an editor and a runtime system, which have been used in two learning situations. The tooling developed and the real use results demonstrate that the QTIMaps model is usable and provides educational benefits. We describe three other assessment activities, showing that the model can be applied to a variety of educational scenarios.

Keywords

E-Assessment, geographical skills, QTI, interactions

Introduction

E-Assessment approaches exploit interactive technologies to support and enhance educational assessment (Conole & Warburton, 2005). Nowadays it is widely accepted that assessment processes, as integral part of education, should support a variety of skills including general and subject matter abilities (Bennet, 1998). The European Qualifications Framework define skill as 'the ability to apply knowledge and use know-how to complete tasks and solve problems. Skills are described as cognitive (involving the use of logical, intuitive and creative thinking) or practical (involving manual dexterity and the use of methods, materials, tools and instruments).' Based on Bloom's Taxonomy (1956) there are six levels of skills complexity that go beyond knowledge, i.e., comprehension, application, analysis, synthesis and evaluation. We address the problem occurring when some skills are included in the educational curriculum but the methods to assess them are not appropriate (Bennet, 1993; Boyle, 2009).

This paper focuses on spatial or geographic information, its representation and related skills. Spatial thinking, one form of thinking, is a collection of cognitive skills, according to the committee of the American National Research Council that has analyzed the incorporation of Geographic Information Science across the K-12 curriculum. The skills consist of declarative and perceptual knowledge and some cognitive operations to transform, combine, or otherwise operate on this knowledge. The key to spatial thinking is a constructive amalgam of three elements: concepts of space, tools of representation, and processes of reasoning, and these elements are present in the K-12 curriculum of most countries. For example, the Spanish curriculum states that secondary education learners should be able to "identify, localize and analyze geographical elements at different scales" and "search, select, understand and relate (...) cartographic information from different sources: books, media, information technologies" (Spanish Government, 2006). Learners should also be capable of understanding processes and how humans influence the environment.

Maps have been the main representation of geographic information for centuries. Information technologies provide useful tools enhancing traditional maps in terms of interactivity and ease of modeling spatial processes. Geographic Information Systems (GIS) support the generation of maps from spatial information, but moreover its analysis (finding patterns in geo-referenced data, for instance) and modeling (such as how the environment will evolve). A GIS should be able to answer the five questions formulated by Rhind (1992), and reflected in Table 1.

Table 1. The five types of questions a GIS should answer

Question	Type of task
1. What is at ...?	Inventory
2. Where is ...?	Monitoring
3. What has changed since ...?	Inventory and monitoring
4. What spatial pattern exists ...?	Spatial analysis
5. What if ...?	Modeling

Nevertheless, GIS's are still mainly oriented to professionals and are difficult to use by the general public, and in particular by K-12 teachers and students, while web maps also enhance traditional maps providing more interaction possibilities. Google Maps is the most popular web map application, offering a world-wide cartography including street-level information for many countries as well as satellite/aerial images at different resolutions. While Yahoo Maps and Bing Maps, are products of Yahoo! and Microsoft with features similar to those of Google Maps, other web maps are compliant with international standards and can show information from Spatial Data Infrastructures (SDIs). An SDI is an infrastructure for sharing geographic information (and meta-information) in a standard way. SDIs are usually created and maintained by public organizations that publish a large amount of geographic information on different topics, such as environment, economy, demography or climatology that can be very valuable in education.

Apart from allowing to access this huge information, web maps enable the combination of different information sources in a single map, and allow the user to identify and draw elements on the map. From the five questions formulated by Rhind, web maps completely support monitoring and inventory, while analysis and modeling only partially. The rich interactions that web maps provide can be used in learning activities for the learner to understand and reflect on space. Web maps can also be used to create activities to assess the acquisition of skills included in the curriculum, both in a formative or summative way.

Very related to web maps is Google Earth (in fact some its functionalities have been recently integrated in Google Maps). Patterson (2007) demonstrates that Google Earth has a considerable potential to enhance teaching methods and supports the development of spatial thinking and other skills (such as critical analysis). Google Earth, as a desktop application, is difficult to integrate in web-based e-Assessment platforms, but is very related to web maps - in fact some its functionalities have been recently integrated in Google Maps. As the potentials described by Patterson can also be applied to web maps, we will focus on them.

ESRI (1998) states that around 80% of data in information systems have a spatial component and consequently can be portrayed in a map. This percentage can also be high in several subjects. Location has a significant role not only in geography, but also in other fields such as history, dialectology, biology (botany and zoology), geology or sociology, among others. SDI's provide information about most of these topics, especially those related to the environment.

However, current learning and assessment e-environments cannot deal with web maps. In fact, this happens for other media with specific types of multimedia interaction. Video sequences composers, chemical molecules viewers/editors or history timelines are neither well supported by these e-environments.

Centering on e-Assessment, there are very few skill-oriented approaches related with maps, and are mostly closed in terms of technologies used and possibilities offered to teachers to customize the designs according to the educational needs (Ridgway & McCusker, 2003). Klaus & Leonhard (2004) propose an innovative assessment tool with their own implementation of interactive maps, but the tool offers a limited number of maps and question types which do not answer the requirements of specific learning situations. Chang et al. (2009) propose a map-based assessment application using Google Maps that allows teachers to edit four types of items (multiple choice, essay question, sequence and map-based questions), but users cannot interact with the maps to answer the questions.

A limitation of these approaches is that they are not using any educational technology standard. Standards should play an important role in e-Assessment tools because they: (1) provide a data model to computationally represent questions, items and results, and (2) enable content reuse across different learning environments. IMS Question and Test Interoperability (QTI) (IMS, 2006) is the e-Assessment de facto standard and interoperates with other IMS specifications such as IMS Learning Design (IMS, 2003). QTI supports questions involving graphical interactions, such as hot spot or select point, among others. Moreover, although QTI does not address interactions dealing with web maps, it supports the definition of new types of items adapted to specific educational goals. Consequently, a valid solution to the integration of web maps (and any other interactive media) in assessment scenarios can be based on the QTI standard.

In this paper we introduce the QTIMaps Model. QTIMaps adopts, extends and combines QTI with web maps services to provide solutions for the assessment of spatial thinking and related skills. The QTIMaps environments will both benefit from the open aspects of QTI and webmaps services: interoperability with other learning services

and standards, and integration of large amounts of up-to-date geo-information provided by SDI's. To validate the model, we present a QTIMaps implementation and its use in a secondary school class and an informal workshop. The implementation uses Google Maps as an example of a web maps service and encompasses an editor and a player based on a QTI engine. The evaluation results extracted from the use of the implementation show that the QTIMaps model is applicable for its intended use, both in terms of educational benefits and usability. Moreover, we illustrate with three additional scenarios that the QTIMaps model supports a variety of assessment activities.

Although QTIMaps is related to (Bouzo et al., 2007), a system for enhancing a QTI engine with maps from Google Maps, the current model is much more complex. QTIMaps model provides a more flexible way to define interactions based on the introduction of interaction methods and validations rules, as will be discussed below. Furthermore, QTIMaps is not restricted to a given implementation of web maps such as Google Maps, supporting a variety of layer types, including those published in SDI's, that can be combined in the same map.

The first section of the paper summarizes the state of the art in the area of e-Assessment specifications and map services. Next, the QTIMaps model is explained. Then, we present the implementation of the model, including an editor and a player, followed by the situations in their real use. The following section introduces other scenarios to show the applicability of the model in formative and summative assessment activities. The final section is devoted to conclusions and to explain the main lines for future work.

State of the art

The QTIMaps model combines the use of a widely accepted assessment standard (QTI) and existing map services, whose state of the art is discussed next.

QTI and related tools

QTI (IMS, 2006) provides an interoperable data model for the representation of questions (items), tests, their outcomes and feedback. It enables thus the exchange of questions and item banks between QTI editors or composition tools, but also with learning systems which include assessment or its outcomes. The data model is defined in abstract terms, but an XML binding is also provided. The latest QTI versions are 2.0 and 2.1. QTI 2.0 focuses on the representation of individual questions categorized by their types of interaction, and contains a set of graphic interactions to deal with images. QTI 2.1 extends QTI 2.0 by considering the aggregation of questions in tests organized in sections, and defines sophisticated ways of producing outcomes reports for the whole test.

A QTI compliant editor (used by a teacher) will turn the test and questions into a set of XML files containing all their information. Similarly,the students' interactions and answers using a QTI compliant player can be assessed automatically and feedback provided.

A QTI engine is the software component managing the QTI data model, processing the XML files and generating the outcomes according to the user actions. We should mention two open source QTI compliant engines: (1) The APIS QTI 2.0 engine (APIS, 2004), which is a modular item-rendering engine addressing the operations required by potential tools as defined in the Open Knowledge Initiative (OKI, 2001) and IMS Web Services; (2) the R2Q2 (Rendering and Response processing services for QTIv2 Questions) (Wills et al., 2006), (R2Q2, 2006), an implementation built from scratch, aimed at providing a complete renderer and response processing engine. Both implementations are limited to the QTI 2.0 (thus only able to process individual items) and cover only some of the question types defined in the data model.

In previous work we considerably extended the items types beyond those covered by APIS and built QTI 2.1 compliancy, resulting in what we called the newAPIS engine (Blat et al., 2007). NewAPIS functionalities include dealing with test context beyond just questions, a wide range of new elements at the test level, and more complex response processing.

Standards for geographic information

Serving maps on the Internet has become very popular in recent years, and a lot of mapping servers implementations exist, both commercial and open source. The Open Geospatial Consortium (OGC, 1994), an international organization composed of companies, governmental agencies and universities, defines consensus geospatial services standards; several OGC specifications have already become ISO standards.

OGC has developed the WMS specification, which defines a service-based interface for a standard web map. The OGC Web Feature Service (WFS) specification is widely used to publish geographic information in vector-based formats. These OGC standards are at the core of the Spatial Data Infrastructures.

Originally developed by Google, KML is a simple XML-based file format to store vector-based geographic information that has been widely popular and became eventually adopted by OGC. GML is another XML-based format standardized by OGC, not popular amongst the general public, but widely used by professionals to share data.

The QTIMaps Model

Web maps provide both new ways of presenting information and new interaction possibilities. QTIMaps is a conceptual model enabling the creation of new types of questions, which integrate the interaction possibilities of web maps (see Figure 1).
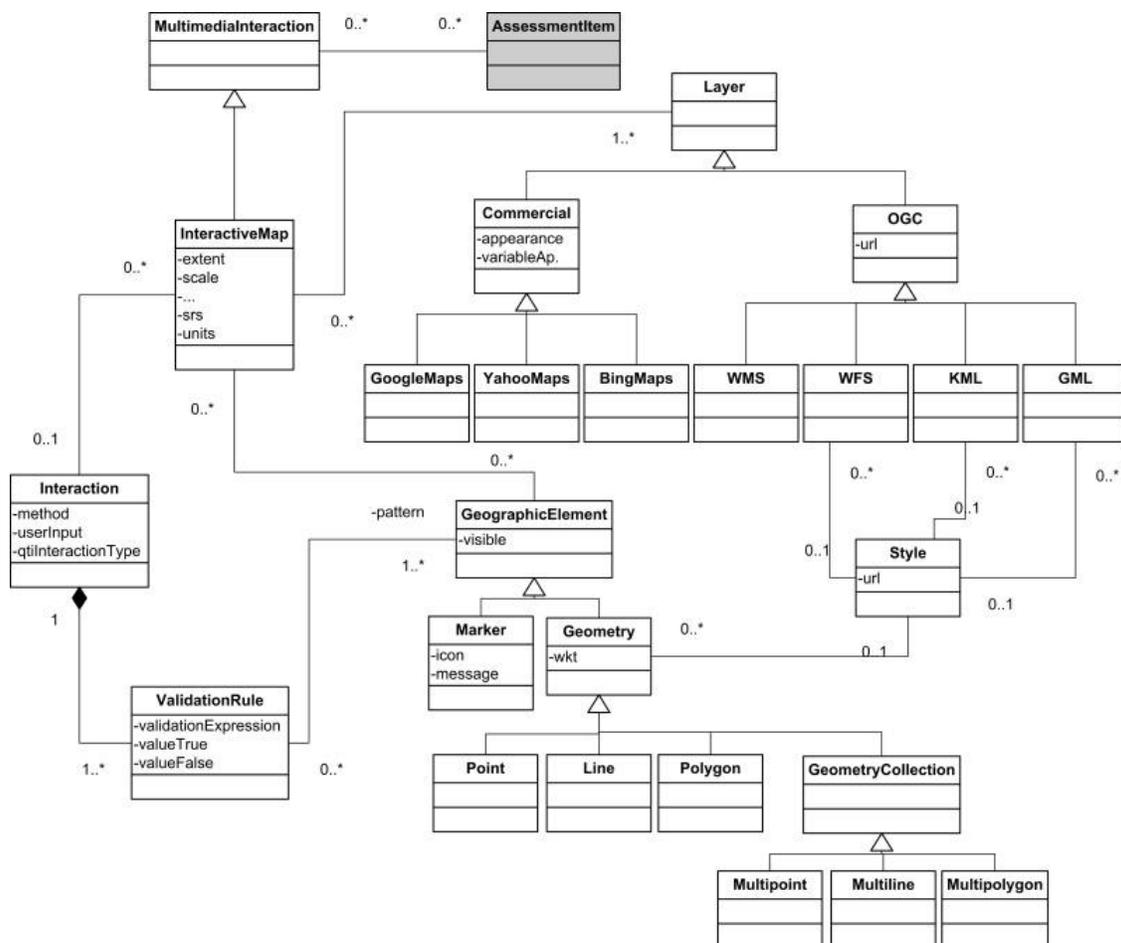

Figure 1. The QTIMaps model

The model is based on the principle of separating the definition of multimedia interactions not supported by QTI from those already supported. This minimizes the changes required in QTI-compliant tools to support new interaction types. A class called *MultimediaInteraction* has been defined to represent any type of multimedia interaction not included in the standard. An instance of *MultimediaInteraction* can be associated to a QTI question (*AssessmentItem* - The MultimediaInteraction instance is related to the *ItemBody* of the *AssessmentItem*) to integrate the interaction into the question. Different types of media interactions would be modeled as subclasses of *MultimediaInteraction*. The *InteractiveMap* class is the subclass of *MultimediaInteraction* that represents a web map interaction.

The InteractiveMap class

To configure how an interactive map is shown, two main properties need to be defined: its spatial *extent* (the rectangle of the Earth shown in the map, i.e. the geographic location of the map) and its *scale*, which actually contains the scale denominator (in a 1:1000 scale). Other attributes may specify whether the user can freely pan or zoom or s/he is restricted to a given extent and set of scales. The spatial reference system -SRS- (*srs* property) of the map must be defined. The SRS (also known as spatial coordinate system) provides a framework for the map coordinates, depending on how the Earth is modeled to obtain the map. An SRS is identified by a code defined by the European Petroleum Survey Group (EPSG), whose list of SRS codes is a de-facto standard for the geographic information community. Finally, the *units* attribute specifies the units of measure of the map, such as decimal degrees, meters, miles, etc.

Layers

An interactive web map can contain one or more layers of information from one or different sources. Different subclasses of the *Layer* class are defined to deal with different types of layers. The simplest map contains one layer - from Google Maps (or Yahoo Maps or Bing Maps), showing the "satellite", "map", "hybrid" or "earth" view depending on the appearance attribute. The *variableAppearance* attribute determines whether the user is allowed to change the map appearance.

These types of layers are very useful for many assessment items, but a huge amount of geographic information is published through SDIs. The *WMS* and *WFS* classes provide support to incorporate these specifications compliant layers through which SDIs publish information: WMS which returns a raster layer and Web Feature Service which returns a vector-based one.

A lot of users and organizations publish their own geographic data through KML or GML, *KML* and *GML* classes are defined to deal with this data. As WFS, KML and GML deal with vector-based information, a style (class *Style*) can be specified to determine how the elements are symbolized in the layer, and therefore shown in the map/tests. For instance, a GML file may contain the geometry (polygon) of a natural park, while the style determines that it will be shown, as a red 2 pixels wide border line, its interior in orange with an Arial bold black label showing the name of the park. Styled Layer Descriptor (SLD) is the OGC style standard.

Geographic Elements

An question dealing with a web map usually requires the learner to identify or to draw geographic elements (such as cities, countries or natural parks) on it. These elements are represented in two ways, by means of either a marker (class *Marker*), or a geometry (class *Geometry*). A marker is an icon placed at a certain location, displaying a message when it is clicked. The marker properties are its *icon* and its *message,* which contains some HTML code. The geometry gives a more precise spatial location representation: it can be a point (similar to a marker), but also a complex line (with several segments) or a polygon, as well as their corresponding collections: multipoint, multiline and multipolygon. OGC provides a standard way to represent geometries through strings, the well-known text or WKT (attribute *wkt*). A style may determine how the geometry is shown on the map, and teacher can define whether the geographic element is shown on the map or kept hidden (attribute *visible*).

Interactions

A map may be associated to an instance of the *Interaction* class, which represents how the user will interact with it to answer the item.

Some items might include a map, without any interaction required to answer the question (as in the question sketched in Figure 2), and then no interaction is associated to the map.
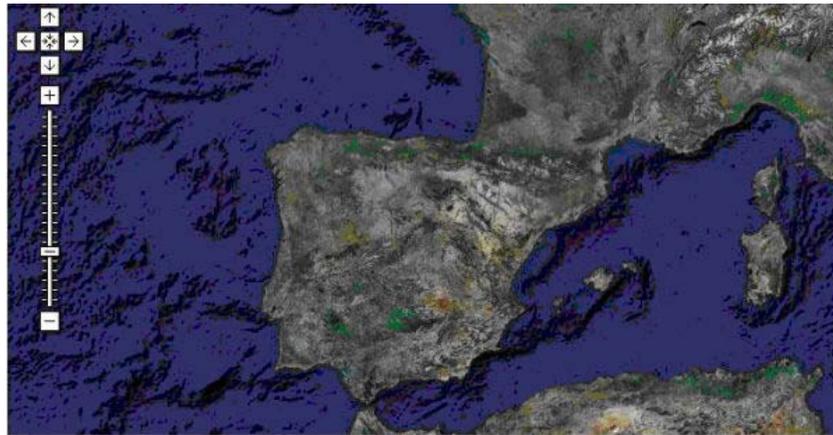
Which is the peninsula that you can see in the map?
- Italian Peninsula
- Iberian Peninsula
- Balkan Peninsula
- Kola Peninsula

Figure 2. Map without interaction required

Four interaction methods are defined:
- *clicking*: clicking on a certain pixel of the map
- *identifying:* clicking on a visible geographic element (marker or geometry) on the map
- *drawing*: drawing a geometry (point, line or polygon)
- *dragging*: moving a geographic element (marker or geometry) to its corresponding place on the map

The *method* attribute defines which one is used, and its allowed values are respectively *click*, *identify*, *draw* and *drag*. As the QTI interaction type influences how to answer the question, the *interactionType* attribute specifies the interaction type defined in the QTI assessment item. Figure 3 shows an example of the same type of interaction method (identifying markers) with two different QTI interaction types: in (a), the learner is prompted to click on the largest Catalan city (a QTI *ChoiceInteraction*), while in (b), the learner is asked to click on the four Catalan capitals in the order according to their population (a QTI *OrderInteraction*).

Which is the most populated city in Catalonia?
(a)

Order the four Catalan capitals according to population
(b)

Figure 3. Interaction method "identifying markers": (a) ChoiceInteraction, (b) OrderInteraction

An *Interaction* instance contains one or more validation rules (instances of the *ValidationRule* class) that represent how the answer is processed to determine wether the answer is right or wrong (or which value is given). The user input is compared to a pattern containing the right answer or one of the possible answers if more than one are considered. The user input depends on the interaction type defined in the *Interaction* class: a position for *click*, a geometry for *draw*, and any geographic element for *identify* and *drag*. The pattern is a geographic element, linked by means of the *pattern* relation with the *GeographicElement* class. The validation expression (attribute *validationExpression*) is a string indicating how the user input is compared to the pattern, and it may contain spatial operators and functions to define a rule as precise as needed.

For instance, in Figure 4 (a) the learner is prompted to click on Italy. The interaction method is *click*, while the validation rule is "*PATTERN contains INPUT*", where PATTERN is a constant that refers to the *GeographicElement* (Italy in this case), INPUT is constant referring to the user input, and *contains* is a spatial operator. Thus whether the user has clicked inside the Italy polygon is validated.

In Figure 4 (b) the learner is asked to draw the border line between Spain and Portugal. The interaction method is *draw* but an exact line cannot be expected as answer, and the validation rules contains a margin of error (specified by the teacher) allowed (e.g. 50 km). The *buffer* spatial function widens the line of the correct response on each side, creating a polygon. The expression of the validation rule is "*Buffer (PATTERN,50000) contains INPUT*". Different validations rules (with different validation expressions) could be defined for different margins of error.

Once the expression is validated, it may be true or false, and a corresponding value can be specified (*valueTrue* and *valueFalse* attributes), which will be returned to the QTI player. In the Italy example, we can set *valueTrue* to "Italy" and *valueFalse* to "Outside Italy", and define the corresponding QTI assessment item as a choice interaction with two choices: "Italy" and "Outside Italy".
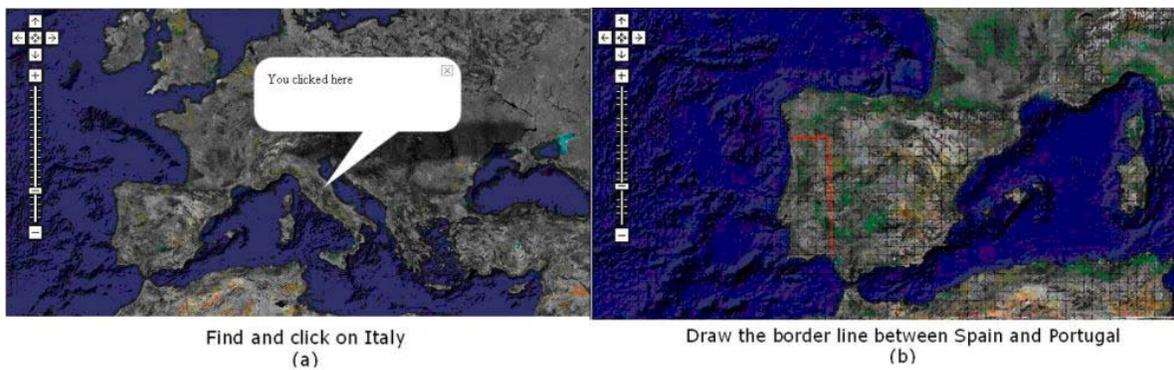

Figure 4. Two examples of validation rules (a) Click on a point, (b) Draw a line

Implementing QTIMaps

We developed a partial reference implementation of the QTIMaps model, covering the whole lifecycle of edition and runtime. It is focused on Google Maps as it is the web map service best known by teachers and students and contains only the corresponding layers types.

This implementation, called *gMapsQTItest* (2010), enables us to test the educational benefits and usability of the model, and represents a reference that developers can use to integrate other types of layers covered by the model and other MultimediaInteractions. After presenting the editor and the runtime system, we describe how the tools have been used in two real educational settings.

The gMapsQTItest Editor

The editor (see Figure 5) provides a wizard that allows the user to graphically define all the configuration parameters and geographic elements as well as the QTI aspects. The author can choose among a set of pre-defined map

interactions with simple validation rules, such as the click interaction method with a point contained in a polygon as validation rule. After the editing process is finished the corresponding QTI documents (a set of XML files) and additional XML document are generated for each item, describing the corresponding map interaction according to the QTIMaps model. The latter is referenced from the QTI item document by means of an InteractiveMap element. The XML documents can be previewed within the editor and further edited (by experts); and can be published establishing the communication with the runtime system.
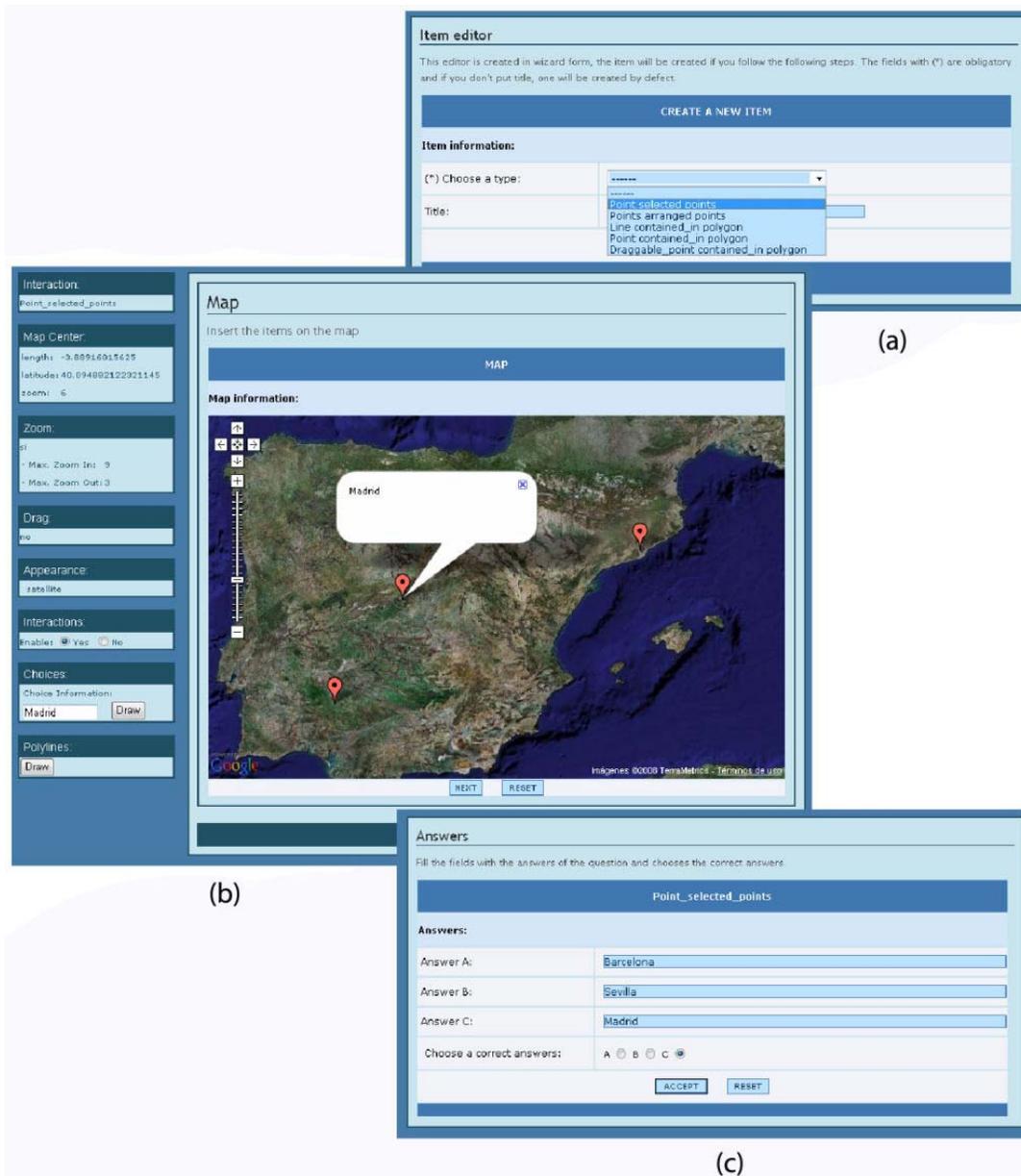

Figure 5. gMapsQTItest editor (a) Selection of the interaction (b) Authoring the map interactions
(c) Editing the QTI part of the assessment

The gMapsQTItests runtime system

The QTIMaps model has been defined so that available QTI engines and players only require to call some additional middleware when a 'new' multimedia element is associated to a QTI item. In the gMapsQTItest runtime system the QTI NewAPIS engine communicates with a middleware that mediates the interpretation of gMapsQTItests by

processing all the elements related to questions dealing with maps. According to the principle adopted in the model the implementation is based on separating the QTI elements from the issues that are specifically related to maps. NewAPIS processes the QTI XML files associated with the test and the items (Figure *6*, step 1). The XML map file is referenced from the *itemBody* of the question (assessmentItem) through the multimedia interaction element, InteractiveMap in our case (see the red box in 6 - ITEM1.XML). When newAPIS detects a QTIMaps element, it calls the middleware (*6*, step 2) which parses the QTIMaps XMLs and generates the code necessary to set the right GoogleMap (*6*, step 3), the functions that process the user's actions on the map converting them into QTI responses that can be managed by newAPIS (*6*, step 4). NewAPIS and the middleware also generate an XHTML code and insert it into a web page that presents the test (*6*, step 5). This XHTML contains JavaScript functions that call the Google Maps API (*6*, step 6). The users can interact with the questions and submit the answers which are computed by newAPIS and the middleware (*6*, steps 7 and 8). Finally the results and feedback are shown to the user (*6*, step 9).
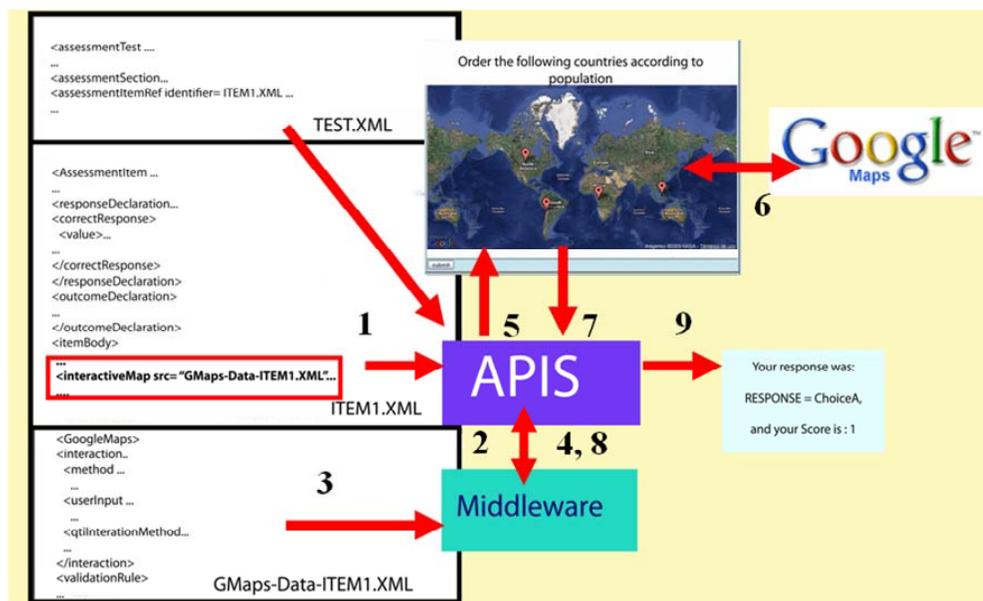

Figure 6. Communication between newAPIS and Google Maps using the middleware

It is important to remark that providing support for other mapping solutions, as the WMS standard, would only require middleware modifications, none in newAPIS.

gMapsQTItest used in learning situations

To validate the fitness-for-purpose of the QTIMaps model from the point of view of educational benefits and usability, it has been used in two authentic learning situations with real users. Both are structured as case studies and analyzed following a mixed evaluation method (Martinez et al., 2003) using several quantitative and qualitative techniques (see Table 2), due to the many contextual factors regarding the students and the teachers.

The questions of the pre-test, the observations and teacher' comments were used to evaluate the familiarity that students and teachers have with web maps applications, more precisely to answer the question: *Did the students demonstrate* **interest** *in web map applications?* The design of the experiences was targeted to understand the educational benefits of using QTIMaps. The questions of the post-test tried to collect data to answer the following research questions: (1) Did the students show a better "attitude to use" gMapsQTItests as compared with a traditional assessments (with blank-maps)? **Attitude** to use" refers to the satisfaction/motivation shown by students in the assessment activity. (2) Did the students perceive the gMapsQTItest as more useful than a traditional one? **Usefulness** refers to the extent to which a student believed that the information provided by the gMapsQTItest would be useful for their learning. Regarding the usability of the QTIMaps solution, the data collected in both cases allowed us to answer the following research question: *Were the gMapsQTItest interactions easy to use/learn?* "**Usability"** refers to the ease with which participants can use gMapsQTItest.

Table 2. Data collection techniques

Data source	Type of data	Labels
Questionnaires	Quantitative and qualitatitive participant characteristics, expectations and opinions before interacting with a gMapsQTI test; evaluation of the experience after interacting with the test.	[Pretest] [Posttest] [UPF-test]
Observations	Notes of observations (opinions done by the participants, behaviour, technical issues, incidents during the activities, etc.) taken by three researchers.	[Observations]
Automatic Data	Students' marks obtained in the gMapsQTI test.	[Marks]
Teacher interviews	Qualitative teacher's expectations, opinions and concerns before and after the experience.	[TeacherComments]

Main Case in a Secondary School in Catalonia: A formal assessment scenario involving a Geography class with 23 students, aged between 14 and 16 years. Several weeks before the exam, the teacher was interviewed in order to know his expectations, doubts and concerns of using an innovative test based on web maps. After presenting him the model and some gMapsQTItests examples in an one-hour session, he designed a test with 8 different questions (see two examples in Figure 7 & 8, and more details of the test, including a video and pictures, can be found at: http://193.145.50.210:8080/QTIMaps/index.html) tailored to the needs of the particular situation. The teacher took into account the students' marks of the gMapsQTItest to compute the final subject mark (summative assessment). The GMapsQTIEditor was used to create the gMapsQTItest which contained different interactions defined in the QTIMaps model. The exam day, the main features of a gMapsQTItest were explained to the students, who completed the pre-test, the gMapsQTI-tests designed by the teacher and the post-test.
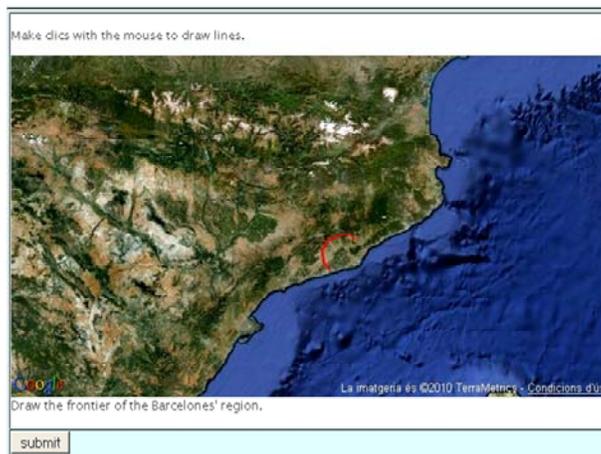

Figure 7. Question 2. Interaction method: draw. User input: line Validation rule: input contained into polygon

Figure 8. Question 6. Interaction method: drag. User input: marker. Validation rule: input contained into polygon

***Secondary cas, an informal open workshop, Science Week at the UPF*:** Students from different secondary schools visited an exhibition at the Pompeu Fabra University (UPF) premises during a Science Week,. 23 of them completed a gMapsQTItest with 8 questions related to the UPF buildings location using 6 different interaction types. It was an informal spatial thinking assessment scenario. We collected more opinions, expectations, technical issues and concerns of the participants interacting with the gMapsQTItest. As this case cannot be considered a formal e-assessment situation its value is more limited, and the data collected has been used to support or reject the conclusions achieved in the main case.

Results

The three main findings and partial results obtained after the evaluation are summarized in Table 3.

First we tried to answer whether students were interested in web map applications. When the teacher was asked about its practices and the familiarity of students with web map applications he said *"my students learn geography using their course textbook, blank paper maps and in some cases I show them some maps extracted from Google Earth using the projector. I do not think my students use GoogleMaps at home* [TeacherComments]" However, to the teacher's surprise, 19/23 students had already used Google Maps out of curiosity [Pretest], and indicated that they liked its functionalities because they can explore using the maps. Some uses stated were: "*...to learn where different countries in the world are located*"; "*…to find maps that I don't find in others sources*" and *"...to see the countries such as Italy or cities as NewYork, which I like"* [Pretest & Observations]. We found out that these students were familiar with web map applications, suggesting that they can use gMapsQTItest quite easily. This is supported by the third finding.

Table 3. Summary of findings, partial results and supporting data

Findings	Partial Results	Support data
1. The students are interested in web map applications using them to explore geographical information.	The 89% of the students have used web map applications to find answers to their personal interests or to find information that they do not found in the course book..	[Pretest] [Observations] [TeacherComments]
	The students' familiarity with web maps facilitates the explanations of how to use gMapsQTItest.	
2. The use of gMapsQTItests elicits students' positive attitudes. The approach seems to also provide significant learning benefits if it is used as formative or summative assessment tool.	Students highlighted that when interacting with web maps: (a) they have more active participation with geographical data, (b) the test is more intuitive, and (a & b) help them to strengthen their geographical memory.	[Posttest] [UPFtest] [Observations]
	Using the gMapsQTItest had a positive effect in their motivation. They like this test because the web maps contain enriched and updated geographical information.	
3. .The students learn quickly how to use the different interactions. The difficulties were on the content of the questions and not related to the interactions themselves.	100% of students in the secondary school passed the test. 5 students had a mark of 4/8 (8 was the maximum score), 6 students had a mark of 5/8, and 12 students had a mark of 6/8. The average mark was 5.30 points.	[Posttest] [UPFtest] [Observations] [Marks]
	The exam question with less correct answers (only 26.08 %) was 6, which used the *"point into polygon interaction using markers"*. This interaction type was also used in questions1 and 3 more successfully answered (95.65% for 3).	
	17 out of 46 students (both case studies) selected the "Draw lines and polygons" as the interaction most difficult to use. However, 56.52 % of the students answered correctly the exam question with this interaction and 78.26% of the students got it right in a question of this type of interaction in the informal workshop.	

The second finding shows the partial results regarding the educational benefits of the QTIMaps model. The data collected indicated that the gMapsQTItest elicited a positive students' attitude, and that gMapsQTItests could be useful to learn and assess geographical skills. The teacher was satisfied with the designed gMapsQTItest, and especially glad about the accuracy of the answer computation of the feedback [TeacherComments]. Learners were somehow scared before the test *"They seem very excited"* [Observations], since their results would be part of the final mark, but not because of using technologies or an unfamiliar scenario. Despite it, there were positive comments after the gMapsQTItest, *"... it is funny and useful to learn!", "... I like this experience because normally we take exams on paper"* [Posttest]. Explicit advantages for learning geographical stated were: *"...I like it, because it doesn't have limits and you have to think much more...It is more complete (than a traditional test with blank maps)"*, *"...it has been an amusing activity and it helps you to remember better", "... I prefer these maps because I can interact with the computer"* [Posttest]. This seems to indicate that interactions demand more active students' participation helping them to remember better the concepts, in line with psychological studies demonstrating that visual images (as web maps) have a beneficial impact in the memory ability of students (Wager, 2005). Moreover, the informal workshop data support these findings with participants' comments as: *"I think that it is an interesting and enjoyable method to study geography (I hated this subject...)", "...it is a different way to do an exam, because you enjoy doing these tasks and this helps to remember better your actions"* [UPFtest].

The third results are about usability; in summary, users can learn and use gMapsQTItests quickly and effectively. Students said: *"... I don't have difficulties to answer any question", "... all the functionalities (such as zoom, pan or drag markers) are very easy!"* [Posttest]. Exam question 6 (see Figure 8) was the one students failed most (17 of 23), but they got good results in questions 1 and 3, which required the same interaction type (dragging a set of markers to specific positions). This indicates that interaction and content difficulties are dissociated, which agrees with the teacher comment that question 6 was more difficult [TeacherComments]. This is supported too by the fact that the most difficult interaction type selected by the participants, *"Draw lines and polygons"*, namely by 17 of the 46, (see Figure 7*Figure 7*) did not have an impact in questions using it having worse answers. Furthermore all the learners passed the exam (the average mark was 5.30 out of 8) [Marks]. These results, combined with the familiarity with web maps revealed in the pre-tests, showed that students understand all the functionalities in gMapsQTItest and can criticize problematic interactions, their opinions being very relevant. Overall, we can say that learners interacted with QTIMaps questions implemented in the test without difficulties of use.

Other learning scenarios regarding the assessment of web map skills

The two previous scenarios cover Rhind's first and second types of questions for geographical skills (see Table 1). In this section we present other assessment scenarios that validate that the QTIMaps model is able to cover the rest of Rhind's types, and other disciplines. These scenarios have been proposed in a recent on-line course for teachers on integrating on-line geographical resources of the Balearic Islands in the K-12 curriculum (Cavada & Navarrete, 2010).

Reasoning about changes in the territory of tourist areas

In this scenario the Balearic Islands SDI (IDEIB, http://www.ideib.cat) is used to analyse how the territory has changed from the situation before the tourist boom of the 1960's. The proposed activity consists in identifying which urban areas in the coast of a municipality of Minorca did not exist 50 years ago. Three WMS layers are used: the 2008 aerial photography (the last available), the one made in 1956 (digitized recently), and the municipalities' borders. The learners have to draw the polygons of the areas that have appeared, which will be automatically compared to the correct ones. The map interaction is modelled as a *draw* method, where the user answer is a set of polygons and each of them is checked deciding whether it is contained inside the right one (applying a buffer to allow a margin of error).

This is an example of a formative assessment activity, where the results of the test will be the basis for debating how tourism has transformed the environment. In this scenario the third Rhind type of question is used.

Reflecting about the Balearic fauna and flora space

In this scenario, the learner is asked to find the areas where certain fauna and flora species coexist in the Balearic Islands. This helps them to identify the typical ecosystems of a Mediterranean island.

This is an example of finding spatial patterns (4th Rhind's question) within a formative assessment activity, where several WMS layers about biodiversity from the IDEIB are used. The type of interaction is similar to the previous one, where the learner has to draw polygons where the species coexist. In geographical terms, the species coverage overlap, and these correct solutions can be automatically computed and compared to the answers provided.

Modelling a new railway line

The learner is asked to propose the course for a new railway line in Majorca connecting the Alcúdia Bay to the current network. The learner is given a simplified model including some of the constraints that the line should satisfy. For instance, it should not go through protected natural areas and it should run close to existing roads. S/he is asked to draw the new line on the map, which will be automatically compared to the two main real alternatives. *Draw* is the interaction method with a line as user input. This scenario is an example of modelling, 5th Rhind's question, and the assessment can be carried out either as formative or summative. Different WMS layers from the IDEIB are used in this scenario, such as railway and road networks, protected natural areas and recent aerial photography.

Conclusions

The integration of interactive maps in learning technology solutions facilitates new ways to assess relevant geographical skills, such as spatial thinking. The QTIMaps model we introduced extends the QTI standard with new interaction types for answering items that exploit the interactions supported by web maps, so that new types of automatically corrected questions can be created. We showed that the model is applicable and supports a variety of assessment scenarios, both old and new. An implementation of the model, using the widely popular Google Maps as web map service and only requiring some specific middleware beyond a QTI engine has been presented. It has been used in two real and different educational situations showing educational benefits going beyond assessment – such as students' motivation increase and memory reinforcement, related to students having to interact actively with web maps to answer the questions – and the usability of the editor and the player. Three additional assessment activities framed in different educational scenarios were described, and showed the potential of the use of the model, as well as the use in the experiences. They cover geography and other fields where georeferencing is relevant.

The QTIMaps model contributes to the state of the art in different lines. The results of the two experiences indicate that the new tools provide a better user experience. Web maps offer navigation possibilities, such as pan and zoom, which allow the learner to contextualize a question in the world (although this can be limited by the teacher) and encourage exploration. Web map viewers as Google Maps provide a familiar user-friendly interface and its use removes barriers perceived by the students between classroom and outside world. The use of OGC compliant web maps gives access to an enormous source of layers with accurate information of different geographically related topics published through SDIs. Moreover, the information is continuously updated by the organizations that produce it, and consequently, once the teacher selects the map for the assessment, the map will always remain up-to-date. The combination of spatial relations and operators allows the teacher to define complex interactions that cannot be done through the existing QTI graphical interactions. Let us remark that the QTI graphical interactions – such as, for instance, SelectPointInteraction - use pixel coordinates and if the image in the question is changed or viewed in a different way, the interaction has to be re-defined again for the pixel coordinates of the new image. In our approach, the coordinates of the geographic elements do not change when the map appearance changes. This lack of flexibility and of semantincs, provided by the information layers of maps, are important reasons to introduce and use the geographic interactions and not keep the QTI graphic interactions. While obtaining and publishing an appropriate map in a QTI graphical interaction can be a hard task, the use of web maps makes it much simpler: since the information is already available on the web, the teacher just needs to select the layers and the area of interest. In this paper, we have shown that teachers have been able to design assessment scenarios based on the model after short sessions where the model, the tooling and some examples were presented.

Our future plans include carrying out a more extended evaluation of the use of the editor with teachers in order to measure the effort required to learn and apply the model. We also intend to combine the QTIMaps model with other learning standards such as IMS LD or SCORM. This combination will allow teachers to include the assessment of geographical skills in their learning designs using educational technology standards in the whole cycle.

The IMS Tools Interoperability working group (IMS, 2007), is devoted to enhance the interoperability of tools within Learning Management Systems, and our approach can be seen as contributing to the cases studied by the group. First, our implementation based on a middleware communicating web maps services and a QTI engine under a strict separation principle can be easily generalized as facilitating interoperability. Second, the model itself could be extended to include other multimedia interactions, beyond web maps. Our future work considers extending it to those types of interactions related to time-based graphical representations (e.g. the multimedia service offered by the TimeLine project, SIMILE, 2003).

Acknowledgements

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