The e-MapScholar project—an example of interoperability in giscience education

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Abstract

The proliferation of the use of digital spatial data in learning and teaching provides a set of opportunities and challenges for the development of e-learning materials suitable for use by a broad spectrum of disciplines in Higher Education. Effective e-learning materials must both provide engaging materials with which the learner can interact and be relevant to the learners’ disciplinary and background knowledge. Interoperability aims to allow sharing of data and materials through the use of common agreements and specifications. Shared learning materials can take advantage of interoperable components to provide customisable components, and must consider issues in sharing data across institutional borders. The e-MapScholar project delivers teaching materials related to spatial data, which are customisable with respect to both context and location. Issues in the provision of such interoperable materials are discussed, including suitable levels of granularity of materials, the provision of tools to facilitate customisation and mechanisms to deliver multiple data sets and the metadata issues related to such materials. The examples shown make extensive use of the OpenGIS consortium specifications in the delivery of spatial data.

Keywords: E-learning; Interoperability; Metadata; GIS; Spatial data

1. Introduction

The potential of the Internet as a medium for delivering e-learning has led to a proliferation of materials and initiatives throughout Higher Education (Gardner, 2003). E-learning resources typically use a range of media (Zerger et al., 2002), are increasingly interactive and customisable and are related to a wide range of traditional learning activities—from lectures and seminars (Ludwig, 1999), through laboratory-based work to field courses (Dykes et al., 1999). Their integration in curricula can span their use as additional reference materials, through ‘blended teaching’ to curricula, which are primarily delivered through the Internet.

The Internet has driven a similar proliferation in the availability of digital spatial data. Such data may be literally freely available (e.g. from the US Geological Survey’s EarthExplorer\textsuperscript{1}) or available through a variety of pricing models from National Mapping Agencies (NMAs) and commercial organisations (e.g. the Ord-
nance Survey’s MasterMap and TeleAtlas’s MultiNet). Whatever the access model, students today have access to a plethora of spatial data, which they can freely manipulate and visualise with access to appropriate skills and knowledge. In the United Kingdom (UK), Higher Education Institutes (HEIs) have negotiated through the JISC (Joint Information Services Committee) access to electronic data from the NMA (the Ordnance Survey) for Great Britain. These data are available to students at subscribing institutions through the EDINA Digimap service, for which more than 86 UK HEIs have now signed up (Medyckyj-Scott and Morris, 1998).

The Digimap service provides three routes to spatial data—in the first a simple client receives tightly constrained but cartographically sensible data from the server in the form of map images. The user can control the features displayed and zoom and pan, but the appropriateness of display at particular scales is controlled by the server. The second mode of use allows the user to select data from different data sets to visualise maps in a Java applet, with the only constraints being imposed by service considerations (for instance it is not possible to create a map for the whole of Great Britain using 1:10 000 source data). The final mode of use of the service allows the user to download raw data as provided by the Ordnance Survey. Such data can then be imported into an appropriate package and manipulated, integrated with other data sources or visualised as required by the user. Users of the Digimap service come from a wide range of disciplinary backgrounds, many of which have a limited tradition in the application of spatial data (Purves et al., 2002). Users from such subject areas are unlikely to have been exposed to a GIScience curriculum, such as are commonly found in the geosciences. Wider use of spatial data across a broad disciplinary background brings with it a need to provide learning materials, which teach the key skills and concepts required to work effectively with spatial data. The e-MapScholar project is a response to this issue and delivers teaching materials that promote the use of geospatial data in learning and teaching, thus also growing the market for the use of spatial data in Higher Education. The project seeks to support learners through the provision of a range of materials that develop skills in the use of digital map data and knowledge of geospatial concepts applicable to a variety of disciplinary backgrounds. Thus, the aim of the project is not to teach students about GIS functionality, but rather about key concepts in utilising spatial data with examples contextually relevant to their discipline.

The development of the e-MapScholar project addresses key issues in the provision of educationally ‘interoperable’ teaching materials and the application of functional interoperability in the provision of such teaching materials. This paper describes the project by exploring three key questions about interoperability in GIScience education, namely:

1. What is interoperability in GIScience education?
2. Why have interoperability in GIScience education?
3. How can interoperability be provided in GIScience education?

Voisard and Schweppe (1998) described a view of an interoperating GIS as a ‘system of communicating services that manipulate alphanumeric or spatial information’. Such a definition envisages that component ‘services’ may be developed and hosted independently thus moving away from a traditional monolithic view of software architecture towards distributed services. Such approaches allow services with no knowledge of each other to communicate through a set of agreed contracts (or in the parlance of software engineering interfaces). Indeed, Včkovski (1998), in setting out a definition of interoperability, argues that by examining both technical and non-technical examples of interoperability it is clear that a key issue in achieving interoperability is defining a contract with agreed common features.

In GIScience the OpenGIS consortium (OGC) was founded in the belief that new and emerging technologies could fundamentally alter the way in which geospatial data and geoprocessing could be accessed (Cuthbert, 1999). The OGC provides an open process for defining interfaces and specifications designed to help promote interoperability between geospatial data and geoprocessing, for example through GML and other GIS Geography Markup Language (GML) implementation specifications, v2.1.1. Open GIS Consortium, 2002. http://www.opengis.org/docs/02-023r4.pdf
Web Feature Services.\textsuperscript{9} OGC specifications have been widely adopted by software and data providers with for example, MasterMap\textsuperscript{2} data provided in GML as standard.

It is clear that interoperability provides a route to reuse of software and data across a wide range of services. However, the implications of interoperable solutions go beyond the technical specification of interfaces for data and services and requires consideration of interoperability at, for example, the semantic and legal levels.\textsuperscript{10} If learning materials are produced for a wide range of disciplines do terms used in those learning materials carry the same meaning in each discipline? Are learning materials produced in an institution using in-house materials copyright free wherever the materials might be viewed? Does 1 h of study time mean the same in Switzerland as in the UK?

In GIScience education, interoperability has implications for both the nature and content of materials. At its core is the concept of sharing materials, and interoperability in GIScience education is defined by Kemp et al. (1999) to imply that one can create ‘materials which are shareable and can have multiple uses in various contexts’ (p. 103). It is argued that both concepts and data must be localised in providing interoperable learning materials, and in turn such localisation requires a set of definitions or contracts between potential users of the materials. Furthermore, materials must be of use in both directed teaching and self-learning. This requires designers of interoperable e-learning materials to consider, amongst other issues:

- the structure, granularity and pedagogy of the material;
- methods of interaction; and
- a framework in which the material can be customised (taking into account language, culture, institution, and (multi) disciplinary contexts).

One important step in allowing such interoperability is the specification of metadata, such as for that specified by the IMS for Learning Objects,\textsuperscript{11} which seeks to specify metadata describing not only educational content, but also context through discipline specific schemas. Maintaining such metadata is a first step in allowing the sharing of learning materials between organisations.

It is clear that at the heart of interoperability, the notion of the sharing of materials, services or data is central. In considering interoperability in GIScience education it is possible to take full advantage of technical aspects of interoperability only if notions of ‘educational interoperability’ are properly addressed. Miller\textsuperscript{10} suggests that to be interoperable one must be ‘actively be engaged in the ongoing process of ensuring that the systems, procedures and culture of an organisation are managed in such a way as to maximise opportunities for exchange and reuse of information, whether internally or externally’.

3. Why have interoperability in GIScience education?

In the previous section we set out to define what interoperability might mean in terms of GIScience education. A basic premise was that materials be produced which were shareable and customisable to different uses through specification of metadata and services which facilitated interoperation. Before addressing the issues in providing such an interoperable service, it is important to determine whether such an approach provides sufficient benefits to outweigh the resulting increased costs.

It is clear that significant overheads are added to the development of any project in developing metadata specifications that are both broad enough to allow a wide range of usage and specific enough to facilitate functional interoperability between components of learning resources. Developing materials that are suitable for adaptation to use in other contexts implies a significant overhead on the already hard-pressed academic’s time in completing the necessary metadata and providing materials, which focus on concept-rich examples where contexts are interchangeable. Can lecturers be persuaded of the benefits of developing such materials?

In GIScience a number of examples exist where materials developed by a wide range of individuals are pooled to create bespoke course materials or national core curriculum. For example, the UNIGIS consortium\textsuperscript{12} delivers distance learning courses internationally leading to the award of a masters degree. A successful business model exists, whereby materials are available from a password-protected site and royalties are paid for their use (Kemp et al., 1999). The NCGIA core curriculum\textsuperscript{13} materials are freely available and provide a valuable, credible and free resource of static materials, which can be inserted into teaching materials with

\textsuperscript{10}Miller, P. Interoperability. What is it and why should I want it? Ariadne (24), 2000. \url{http://www.ariadne.ac.uk/issue24/interoperability/intro.html}
\textsuperscript{11}McKell, M., Thropp, S (Eds.), IMS Learning Resource Meta-Data Information Model. 2001. \url{http://www.imsglobal.org/metadata/imsmdv1p2p1/imsmd_infov1p2p1.html}
\textsuperscript{12}UNIGIS homepage. \url{http://www.unigis.org/}
\textsuperscript{13}NCGIA Core Curriculum. \url{www.ncgia.ucsb.edu/giscc/}
minimal effort. However, these materials are in general interoperable only in the sense that they provide a resource providing assistance in developing course content for lecturers—they are not designed with localisation in context or space in mind, but rather to give sufficiently broad brush examples to satisfy a general audience. Finally, the GITTA project\textsuperscript{14} provides a relatively complete online GIScience curriculum for Switzerland, which makes extensive use of Flash to provide interaction. In this case, the partners in the project developed materials, which closely integrated with existing curricula. Brox (2003) describes a number of other examples of Internet-based learning materials for GIScience education. Such examples show that materials have already been developed, which to a greater or lesser extent, are shared across a broader community.

Functional interoperability and developing technologies in GIScience provide us with opportunities to innovate in the provision of learning and teaching materials. Web-based learning is most popular with students when some level of interaction is provided (Sims, 1999), but to be most effective these interactive examples should be context specific. This in turn implies that for different disciplinary backgrounds examples should be ‘localised’—for example tailored to geographical regions or contextual backgrounds that form part of a student’s learning. The costs of developing tailored interactive materials are high and provide a primary motivation for developing materials, which are shareable (and thus by our definition interoperable). By sharing materials, institutions can concentrate on developing high-quality materials within their specific realm of expertise, and thus increase quality and reduce duplication (Brox, 2003). Such arguments provide the strong motivations for moving towards the development of truly interoperable materials for GIScience education.

4. How can interoperability be provided in GIScience education?

Central to the e-MapScholar project is the provision of teaching and learning materials, which facilitate use in a range of disciplinary contexts. The materials have as an underlying theme the use of spatial data, and specifically those data provided by the Digimap service. However, the concepts illustrated using spatial data are broadly independent of the particular data source, which should rather be viewed as providing a context for examples. Through consultations with teaching staff, three main areas were identified as key conceptual interdisciplinary domains for the e-MapScholar project:

\begin{itemize}
  \item Working with digital map data;
  \item Data integration; and
  \item Data visualisation.
\end{itemize}

These domains provide the highest level of granularity in the project, and can be considered as broad themes to which learning materials are attached. Within each theme a set of learning resources have been developed, with each resource aiming to provide a coherent set of learning materials. Learning resources themselves consist of a set of learning units, the lowest level of granularity visible to a student. Learning units consist of a set of learning objectives, interactive tools and learning objects illustrating key concepts within the unit and some tools providing formative assessment. Fig. 1 illustrates the components making up a learning resource and their relationships.

In themselves, such materials are similar to those provided by many other online courses in GIScience and education in general. However, the design of the e-MapScholar project has from the first wholeheartedly embraced the concept of customisation, and thus interoperability, across disciplines. Through consultation with academics interested in using materials it was ascertained at an early stage that customisation should allow the insertion of local examples in a spatial sense, and the provision of disciplinarily specific examples. It was also suggested that the reassembly of existing learning units to provide new resources would be a useful facility.

To allow such customisation the design process of the e-MapScholar project had to consider several key issues related to notions of interoperability in GIScience:

\begin{itemize}
  \item At what level of granularity should customisation be possible?
  \item How could materials be provided which allow customisation of both locally and disciplinarily specific examples?
  \item How could such materials be stored so that they could be accessed and modified without a detailed understanding of the underlying functional interoperability?
  \item What metadata were necessary to address such issues as lineage and ownership?
\end{itemize}

Interestingly, these issues can be seen to have some considerable overlap with the list of unresolved problems presented by Kemp et al. (1999, p. 111) in their discussion of GIScience education and interoperability. The implementation described here is not the only, or necessarily the best possible solution to these problems but we believe it goes some way to addressing the agenda suggested by Kemp and others.

\textsuperscript{14}GITTA home page http://www.gitta.info/
4.1. To what level of granularity should customisation be possible?

Customisation can be provided at many different levels, ranging from providing mechanisms allowing users to write materials from scratch to simply allowing users to copy materials to a local space and add some localised introduction or reorder the basic units to form new materials. In the e-MapScholar project customisation is possible at the level of granularity of learning resources, units and objects. Customising a learning resource essentially involves either a reordering of the learning units, the deletion of particular units, the insertion of different learning units or some combination of the above. As part of the customisation process it is necessary to enter new metadata indicating the learning objectives of the new resource and its intended audience. Lineage information is stored, and the learning units used in the resource are flagged so that customisation at a lower granularity, namely, that of the component units and objects does not invalidate the resource.

Customising a learning unit is intended to facilitate the use of the materials across a broad range of disciplines. A unit is made up of a set of learning objects as shown in Fig. 1, and any of these objects can be customised. In the case of text, this might involve changing the text to refer to a disciplinarily specific example, whilst in the case of a map or tool alternative data might be used to illustrate a concept. The assumption is that customisation is mainly necessary to localise the materials but that the concept being illustrated will remain largely the same. It is not possible to completely reorder or delete the learning objects chosen by the original author in illustrating a concept. Fig. 2 shows the view presented to a student of a typical learning resource and Fig. 3 illustrates a single page from a learning unit within that resource.

4.2. How could materials that allow customisation to locally and disciplinarily specific examples be provided?

The e-MapScholar project is focused around spatial data and as such the key customisable elements are tools illustrating the use of such data. At the simplest level, all tools can be customised by changing the bounding box of the spatial data. For example, a lecturer in Wales might use data from Snowdonia to illustrate ideas on hill shading instead of the Lake District in England. Beyond this simple level, the nature of the customisation varies with different tools. Fig. 4A shows a sample page from a learning unit illustrating an instance of tool visualising elevation data and an interface allowing customisation.
Fig. 2. Student’s view of a typical learning resource showing component units and learning objectives.

Fig. 3. View of a single page in a learning unit illustrating use of a tool to display elevation data.
of that tool (Fig. 4C). The tool shown in Fig. 4 is the same as that shown in Fig. 3, with a lecturer being able to select the two different instances of the tool using the customisation interface shown in Fig. 4C. In Fig. 3 the tool has been configured to allow the student to toggle through a range of visualisations of elevation data (e.g., 1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29, 31, 33, 35, 37, 39, 41, 43, 45, 47, 49, 51, 53, 55, 57, 59, 61, 63, 65, 67, 69, 71, 73, 75, 77, 79, 81, 83, 85, 87, 89, 91, 93, 95, 97, 99, 101, 103, 105, 107, 109, 111).
slop, aspect, etc.) for the Cairngorms, whilst in Fig. 4 the tool is configured to show only elevation data for the Scottish borders, with the student able to select different colour ranges and values.

In the case of mapping tools, an interface is provided by which the lecturer can customise maps in terms of both scale and content. Not all spatial data are equally applicable at all scales, so the lecturer can choose between various mapping products depending upon the scale of the map they wish to present to the student.

Customisation is possible because the tools conform to OpenGIS standards. Three specifications have been deployed to date to support customisation within e-MapScholar. The Web Map Service (WMS) Interface Specification\(^\text{15}\) is used to provide static maps. The Web Feature Service (WFS) Interface Specification\(^\text{8}\) an interface that supports query level access to vector data (points, lines, and areas (polygons)) in spatial databases. Unlike the WMS which returns an image, a WFS returns data. Finally, the Web Coverage Service (WCS)\(^\text{10}\) supports the provision of ‘coverages’ containing values or properties of geographic locations such as elevation data. In this case, a client-side tool is responsible for rendering the data (The tool illustrating elevation data in Figs. 3 and 4 utilises the WCS).

Currently all the data are provided via a set of OpenGIS services which access the spatial databases underpinning the Digimap service. Since Digimap holds coverage of Great Britain, a lecturer may customise the tools to any location therein. However, because e-MapScholar is built upon OpenGIS Implementation Specifications, the Digimap servers could be replaced with any other OGC compliant servers. Thus if it was desired to use examples localised to, for example, the United States, providing OpenGIS compliant services existed, there is no reason why the tools could not use these underlying data to illustrate various concepts, licence issues not withstanding. This, we believe, is a very powerful capability.

4.3. How could such materials be stored such that they could be accessed and modified without a detailed understanding of the underlying functional interoperability?

Key to encouraging the use of materials and their customisation are user-friendly mechanisms for accessing and modifying materials. MapScholar these data are accessed through the use of a bespoke content management system (CMS), which allows users to assemble and edit materials through the use of online forms. In this sense the CMS is a sub-component of a learning content management system (LCMS). A LCMS is an environment where lecturers can create, store, assemble, reuse, manage and deliver learning content from a central object repository. The main difference between the e-MapScholar CMS and a LCMS is that the CMS focuses on the modification of existing units and does not provide an authoring interface to create completely new learning units from scratch. Rather, it focuses on allowing users to modify and reorder existing learning units and objects to create new learning resources (Fig. 1 illustrates the hierarchy of elements making up a learning resource).

The CMS is web-based and provides user-friendly mechanisms for accessing and modifying materials. Users can edit materials through a mixture of text boxes and dialogs (the wizards proposed by Kemp et al., 1999) in order to modify existing learning units and create new learning resources without any knowledge of the underlying materials. Figs. 4B and C illustrate the use of the CMS in modifying an existing learning unit. The menu bar on the left-hand side of Fig. 4B allows the lecturer to navigate between pages within a unit. The content and associated metadata for a page are contained on the right-hand side of Fig. 4B, and clicking the Customise Tool button results in presentation of the tool customisation screen shown in Fig. 4C and discussed in Section 4.2. The lecturer may modify the text displayed on a page using a set of simple HTML-based forms. The CMS is based on a learning object model and is implemented using a combination of XML, XSLT, CSS, and Java Servlets. An important factor is the separation of content from presentation. The materials themselves are stored in XML, for which document type definitions (DTDs) have been defined at the level of the learning resource and the learning unit. This offers the potential to publish to a wide range of formats, platforms, or devices (for example mobile devices such as PDAs) from the same source material.

4.4. What metadata were necessary to address such issues as lineage and ownership?

Underpinning the CMS is a large volume of metadata based upon the IMS Learning Resource Meta-data Information Model.\(^\text{9}\) A CMS Metadata Model for both resources and units is defined based on the IMS standard. Within the model metadata are divided into two groups of elements. The first group consists of shared information, which is seen by both students and lecturers and includes elements such as resource or unit title, author(s), institution of author(s), and learning objectives. The second group is instructional metadata.


This includes elements such as contributors to the units, e.g. graphic designers, legal and copyright information, intended audience, life cycle status and version and information for indexing of the unit or resources such as subject terms and the geographic coverage of the examples given in the unit. IMS learning resource metadata records can be produced from this shared and instructional metadata.

It became clear as the CMS was developed that the IMS standard had certain deficiencies. Key amongst these were firstly, the lack of a definition of the life cycle of a unit or resource and secondly, a way of recording the lineage of the units as they were reused. Resources and units are created, used and may be removed, and therefore evolve through a life cycle. The CMS Metadata Model was therefore extended to take account of the lifecycle of a learning resource and unit; this is used by the CMS to manage resources and units.

Keeping track of the lineage of the units as they are used is important not least because of the issue of ownership of the intellectual property rights (IPR) of units. During the design stage lecturers raised two concerns. First, will an original author of a unit or resource wish their name to continue to be associated with a unit or resource as it is reused and customised given that they may not be content with subsequent modifications? Secondly, must a resource or unit display the name or names of all the lecturers who have customised the original materials? This could result in large metadata records. Legal advice was sought on these issues. As a result it was agreed that the following capabilities were required:

- an author history be maintained in the metadata;
- a disclaimer be provided which states that the original author(s) do not bear any responsibility for the secondary use or any interpretations of their material; and
- a facility for the removal of an author’s name from the metadata on request.

As a consequence, the original author and current author are now recorded as part of the metadata of any documents. A registry is used to maintain the author history and this can be used to describe the ancestry of all documents in the system. Thus for any unit or resource, a list of previous authors can be generated. The complexity of these, and related metadata issues, illustrate well some of the institutional, legal and cultural challenges in producing interoperable materials in GIScience.

5. Conclusions

This paper describes the e-MapScholar project, which aims to provide interoperable learning materials relevant to spatial data sets available to UK HEIs through the Digimap service. The paper describes elements of functional and conceptual interoperability provided by the project through the development of:

- a framework designed to encourage the sharing and reuse of learning materials developed for GIScience;
- a CMS to allow academics to quickly and easily localise examples geographically and contextually without knowledge of the underlying data structures of learning units;
- use of existing OpenGIS Specifications to allow interoperation between underlying spatial data sources for interactive tools illustrating the use of spatial data; and
- metadata facilitating the sharing and reuse of materials, which tracks lineage and authoring histories of materials.

A set of tools have been developed which take advantage of the technical interoperability facilitated by implementation of OpenGIS compliant web services (Web Map, Feature and Coverage Services in this case). The tools take advantage of these interfaces to allow simple customisation of geographical context through the use of data available from Digimap. Further, any server providing OpenGIS compliant interfaces can be used by e-MapScholar, further demonstrating the potential benefits of interoperability in allowing sharing of data and provision of a wide variety of examples.

A content management system has been developed to simplify customisation of resources, units and tools through the use of a set of ‘wizards’. Lecturers can customise materials at different levels of granularity—by changing the content of an individual page or pages within a unit, or reassembling a set of units to create a new learning resource. We believe this is a key component in providing educational interoperability addressing the ideas of sharing and reuse of materials discussed by Kemp et al. (1999). Crucially, lecturers can easily localise examples geographically and make simple modifications to learning materials to enhance their disciplinary relevance and encourage the production of shared resources.

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