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Using Extensible Markup Language (XML) for the Single Source Delivery of Educational Resources by Print and Online: A Case Study

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This article seeks to provide an introduction to Extensible Markup Language (XML) by looking at its use in a single source publishing approach to the provision of teaching resources in both hardcopy and online. Using the development of the International Baccalaureate Organisation's online Economics Subject Guide as a practical example, this discussion reflects on some of the key technological and educational strengths and limitations of using XML for this kind of approach.

This article seeks to provide educators with a brief introductory overview of Extensible Markup Language (XML) by looking at its use in a single source publishing approach to the provision of teaching resources in both hardcopy and online. Using the development of the International Baccalaureate's online Economics Subject Guide as a practical example, this discussion reflects on some of the key strengths, as well as technological and educational limitations of using XML.

In 2001, the International Baccalaureate Organisation's[1] (IBO) Online Curriculum Centre began development of a single source approach to improve the delivery of teaching resources in both printed and web-based educational resources. XML was introduced so that a single source of content could be used in different ways and formats according to the needs of both content providers and end-users.

The pilot project to test the technical and educational effectiveness of this process of "single source publishing" was the Economics Subject Guide for the International Baccalaureate (IB) Diploma Programme[2]. Single source publishing is a process whereby a master source of information is prepared in an authoring and editorial process, and then used to drive a production process to delivery to end-users through mass print and the Web. Using this approach, paper-based documents would look and be structured as normal; however, the online version of the same content would be reformatted in an automated process to be more interactive and web-friendly.

The use of XML within this kind of data-base driven framework has developed tremendously during the last decade; however, many educators are still coming to terms with how to best apply this technology to a learning object approach to the delivery of educational resources, so that learning content is reusable, interactive and can be customised by the end-user[3]. The following discussion explores some of the issues arising from the use of single source publishing to drive the delivery of printed and online curriculum resources to IB teachers. Using the development of the Economics Subject Guide as a practical example, this article reflects on some of the key technological and educational limitations and advantages of using XML.

The first section of the article sets out the context of discussion, in which a single source publishing approach was adopted by the *Online Curriculum Centre* (OCC) to enhance the way teaching resources were delivered to teachers of the IB throughout the world. The second part provides an introductory overview of XML. The third part describes the workflow process required to repurpose the Guide using this approach. The fourth section looks at the challenges and limitations encountered when implementing XML. The final part of this article looks at the technological and educational strengths of this XML-based single source approach.

While the purpose of this article is to serve as an introduction for educators considering the use of this kind of data-base driven approach for e-learning and the provision of educational resources, a basic understanding of HTML is assumed by the author. The following acronyms are used throughout this article:

Table of Acronyms

CSS	Cascading Style Sheet
DTD	Document Type Definition
FOP	Formatting Objects Processor
HTML	Hypertext Markup Language
IB	International Baccalaureate
IBO	International Baccalaureate Organisation
OCC	Online Curriculum Centre (IBO professional development website)
PDF	Portable Document Format
SGML	Standard Generalised Markup Language
W3C	World Wide Web Consortium
XML	Extensible Markup Language
XSL-FO	XSL Formatting Objects
XSLT	Extensible Style-sheet Language Transformation

CONTEXT

When the Online Curriculum Centre commenced development of a single source publishing approach using XML in 2001, its website was seeking to deliver educational resources and services in English, French, and Spanish to over 25,000 IB teachers working in around 1,300 authorised IB schools across more than 100 countries. Originally established in 1999, this password-protected website was developed in response to the expansion of the IBO across the world and the need to disseminate information quickly and efficiently. Designed to support the IBO curriculum in all three academic programmes, this website is an online database and digital repository of educational resources for IB teachers to communicate and share their knowledge. The site enabled teachers to: (a) view curriculum materials; (b) exchange details of useful resources (e.g., websites, books, magazines) and teaching ideas; (d) discuss curriculum issues with other teachers transnationally; (e) take part in online training through bespoke, curriculum-specific educational modules; and (f) keep up to date with IB curriculum developments and general news about the IBO.

Redevelopment of the new OCC website began in the latter half of 2001, which involved overhauling its frameworks for the delivery of Subject Guides, teaching materials and asynchronous discussion forums. Redevelopment of the site attempted to address the delivery of an estimated 3.2 million words of content (e.g., Subject Guides, general news and information) targeting three areas: (a) the storage of data—in particular, how curriculum

documents and other teaching resources were stored; (b) the dissemination of data—how documents were prepared and delivered to users (IB teachers, school administrators, and support staff) through both print and the Web; and (c) the presentation of data—how the documents looked both on paper and on the Web, which at the time was generally the same because the majority of content on the OCC website was taken directly from printed source files stored in Portable Document Format (PDF).

A major component of the renovation of the OCC was to develop a framework for publishing online versions of curriculum materials, redesigning them from their original format for paper publication. The goal was to develop a framework in which content could be repurposed (i.e., restructured and reformatted) from standard printed publications to the Web in a way that maximised the medium. Storage of OCC data, such as curriculum documents and other teaching materials on the IBO's internal computer network, came from multiple sources and formats (e.g., PDF, HTML, MS Word, and WordPro), which lead to inefficiencies in data management and unnecessary duplication of labour. Previously, teaching resources such as Subject Guides were prepared in printed format (typically standard black and white A4 sized documents), then marked-up in HTML in a separate process for the OCC website. The layout and format of online versions were predominantly text-based and looked similar to the printed versions. Often, the PDF used for printing was directly uploaded to the Web as a single file. In some cases, these PDF files designed for printing purposes were often scanned off a master document and posted directly to the website in a format that was sometimes difficult to view with a web-browser—especially when these PDF files were extremely large in size (particularly those containing images). Furthermore, these files were typically "static," in the sense that they were not designed for interactivity (e.g., many did not include hyperlinks or navigation facilities). This static way of storing content in PDF and HTML was not dynamic and under-utilised the power of the database driving the OCC website. Furthermore, raw content was formatted using different word-processing, web-design, and other packages without a single standard approach.

A system was needed that "captured" content early on in the authoring and formatting stage so that the content could be marked up for print and the Web in a unified process. Consequently, a single source publishing approach using XML was adopted. The primary aim was to enable teachers to access two differing versions of syllabus, each with separate functions. The

Diploma Programme Subject Guide for Economics was used as the proof of concept for this approach. This Subject Guide consisted of around 7,000 words of text outlining the objectives, syllabus, and assessment requirements for the subject. The IB Economics curriculum was taught at two levels, Higher Level (HL) and Standard Level (SL), as outlined in the Subject Guide (IBO, 2003a). Though published in English, Spanish, and French, this article will focus on the development of the English language version of the Economics Guide.

A Brief Introduction to XML

XML[4] is a source-markup that provides a set of rules and guidelines for designing text formats that enabled content providers at the IBO to structure, store, and deliver data (such as Subject Guides) to teachers through the Internet and in printed hardcopy formats. XML is a text-based markup language that is customisable ("extensible"), enabling users to construct their own specialised markup languages to transmit data (Bray et al., 2004; Bradbury, 2001). It provides a basis for defining specialised markup languages used to transmit formatted data (W3Schools, 2004). This "meta-language" (i.e., language that can create other languages) was developed in response to some of the positive and negative experiences of other languages; namely, HTML and Standard Generalised Markup Language (SGML). Developed so that contractors and suppliers could exchange large technical documents in areas such as the U.S. Department of Defence, pharmaceutical and aerospace industries (Kasdorf, 2003), SGML was developed "for supporting the management of heterogenous information resources of the Internet and to facilitate communication between various software applications" (Salminen, 2005). Development of XML began in 1996 as a subset of SGML as a standardised basis for individuals and organisations to exchange information using their own vocabularies and structures in ways that were easier to implement on the Web (W3C, 2003; Bray et al., 2004; Bosak & Bray, 1999). XML is also used as a basis for data interchange between software applications. XML's designers drew from: (a) the positive aspects of SGML; while (b) seeking to address some of the negative aspects of HTML, which had a lot of limitations as a markup language (Kasdorf). XML arose from the need to develop something simpler and clearer to use. By 1998, W3C recommended XML as a standardised approach to data-handling (W3C, 2003).

Kasdorf (2003) writes that XML "provides a well-defined, broadly accepted syntax for creating markup schemes to [enable] the development of tag sets focused on projects as small as a single book or journal…or whole collections or classes of books or journals…or to achieve a particular functionality" (p. 87). It consists of elements (markup that encloses content), attributes (which embellish content), comments (such as human-readable annotations) and entities (which enable any chunk of digital content to be given a name and then referred to by that name instead of being directly incorporated into the XML document itself. These chunks can include content of external files, including non-XML files.)

Rather than replace HTML, which is primarily a presentational format "designed for a specific way of viewing the given content" on the Web, XML is a "language designed for marking up content of all sorts (text, graphics, computer code, commercial information, intellectual information) in order to specify what the component parts of that content are, and to describe them" (Kasdorf, 2003, p. 91). Like HTML, XML makes use of tags (words bracketed by "<" and ">") and attributes (of the form name= "value"). Unlike HTML, XML has a potentially infinite number of tags. Data stored in an XML file usually consists of strings of words, rather than numbers. These words can have explicit meaning assigned by the creators of the content that refer to information about what the elements in the source content are and how they relate. As Kasdorf (p. 91) further explained, "XML is, in its best use, a source markup, designed to be transformed into something else, to be archived and used in different ways." As one of the many tag sets that can be defined in XML, HTML is one of the many possible outputs from an XML source.

Where HTML specifies what each tag and attribute means and often how the text between these tags will look in a browser, XML uses the tags only to delimit pieces of data, and leaves the interpretation of the data completely to the application that reads it (Bradbury, 2001). For example: use of the "<p>" tag in an XML file does not necessarily define a paragraph as it does in HTML. In XML, it can signify any attribute. In relation to the Economics Subject Guide, these tags were created to suit the specific needs of the content providers and in a language that participants in the creation and dissemination of the Guide could understand (i.e., technical developers, designers, educational authors, and lay-persons)[5]. Any tag can be created and used in XML, provided it is used in a pair with a closing tag to match any opening tags, so it has a potentially infinite number of tags—unlike

HTML, which has a fixed set of tags and will typically attempt to display a webpage even though it may be missing certain tags. XML will not tolerate any mistakes; consequently, browsers may display inappropriately tagged data as a "jumble" of data (Berners-Lee, Hendler, & Lassila, 2001, p. 32). This "draconian error handling" is deliberately designed by the developers of XML to promote stability in data-handling (Kasdorf, 2003).

WORKFLOW

For the Economics Subject Guide, XML was not only used to generate the HTML version for the Web, but also to generate fully formatted PDF versions of selected portions of the same source of content, which could be mass printed and made available to teachers in hardcopy. The basic steps for repurposing the Economics Guide for viewing on the Web and mass printing were as follows:

Step 1: The Economics Guide was created in Microsoft Word, through which the basic styles (e.g., for topic headings) were formatted. Word was used because the software was familiar to authors;

Step 2: The document was then structured and tagged according to a Document Type Definition (DTD). A DTD is a kind of template for the XML; it is a separate file that defines what should go where within an XML document and in what order. A number of DTDs have been defined and released to the community to use. For the Economics Subject Guide, a specific language was created and defined as a DTD based on a standard *DocBook* DTD. *DocBook* is a general purpose XML DTD specifically suited to book and journal publishing. It features a simple schema that served as a good starting point because it was available freely and applicable to the Subject Guide, in that it was not very complex in structure and had a relatively simple format. This DTD stated what elements must be present, which ones were optional, what their attributes were and how they were structured in relation to each other. The XML document containing the Economics Guide was written to comply with this DTD to ensure that the document could be processed for display on the Web. YAWC software[6] was used to insert *DocBook* tags into the Microsoft Word document to define the structure of the Guide (e.g., sections, heading levels, tables, lists, etc.);

Step 3: The document was then validated to ensure that it conformed to the DTD structure;

Step 4: This involved exporting / converting the Guide to the "raw," single source XML document that served as the source for both online and printed versions. Having styled the content in Word format using *DocBook* tags, the Guide was then exported from YAWC to create a basic, structured XML document. (Essentially, Word styles were replaced with XML tags.) This XML was then refined using XMetaL software to define in more detail certain features of the XML document, such as roles, attributes, and table widths for the layout of the Guide.

This XML document also served as a container for metadata; that is, information about the content in the Guide. Metadata was added consisting of attributes and values that identified, for example, the language in which the Guide was written (i.e., English, Spanish, or French), the author, the teaching level (HL or SL), publication date, security, rights information, version, and so forth. Other metadata was added describing how the content of the Guide would appear and relate to other online content (such as the online discussion forums). For the online version, this metadata enabled the Guide to be customised to deliver the relevant material to end-users, pitched at a teaching level based on a user-profile stored in the OCC system. For example, when a Higher Level Economics teacher requested the Subject Guide online, the data-base driving the website was programmed to find the data tagged at that teaching level and covering only the subject matter required in the teacher's working written language. The system was programmed to find the data tagged at their teaching level, visually highlighting the teaching level of subject matter specified. If, on the other hand, a print-out was requested, the entire Guide, including both Higher and Standard Levels, was automatically generated from the same single source.

Metadata was further added to the online version of the Guide so that new features, such as graphics, illustrations (e.g., Demand and Supply Curves), and other features could be hyperlinked to relevant sections. Keywords and headings were identified and linked to a definition within a glossary. Selected aspects of the syllabus could, in the future, be extracted from the single source in a summary form for the teachers to distribute to students. The Subject Guide also incorporated the use of hypertext to link to a facility for adding resources. Furthermore, key words, phrases, and headings were linked to other resources, which could be added by users to the relevant area

of the Subject Guide. Users were able to add different types of resources to selected keywords and headings. Resources included information about books, websites, and teaching ideas, such as course outlines, lesson plans, student activities, tests, and quizzes. Resources such as specimen questions, diagrams, glossary, and command terms were added later to the online-only version of the Guide by clicking on specific words or phrases within the syllabus. The Subject Guide was also tagged to enable portals to other related resources on the World Wide Web ([Web]; e.g., Biz/ed 2004). A holistic approach was taken in an attempt to integrate the Guide with the OCC website's other facilities, such as the discussion forums.

Step 5A: The XML file containing the Subject Guide was then converted into HTML for viewing on the Web using an Extensible Style-sheet Language Transformation (XSLT). XSLT is an XML-based language for transforming XML into other formats. (Bradbury, 2001; Clark, 1999; Holman, 2000). For the Guide, XSLT was used to take the XML file containing the Subject Guide and convert it to HTML. The XSLT style-sheet rules ensured that certain "online-only" features were recognised in the XML document (such as the Subject Guide's glossary of economic terms, graphs, and other illustrations).

Step 5B: While one XSLT was used to create the online version, another was used to create a printed version (in conjunction with XSL-FO to generate the PDF) using the same source-file in XML. This XSLT style-sheet effectively converted the same XML file to a format for print (FOP[7]). The style-sheet ensured that online-only tags were ignored for the printed version. A Java application, XEP, was used to render the content in PDF. The Guide was then printed for mass distribution to IB schools.

XML was used within this single source approach for four main reasons: (a) to encode and structure information from one source; (b) to enable the format, or "look," of the Guide to vary according to where and to whom it was being delivered (be it in printed hardcopy or via the Web); (c) to exploit the openness of XML standards; and (d) though not fully exploited during the pilot phase, XML can be used as a storage medium. To understand how XML works, it is worth explaining these reasons in further detail.

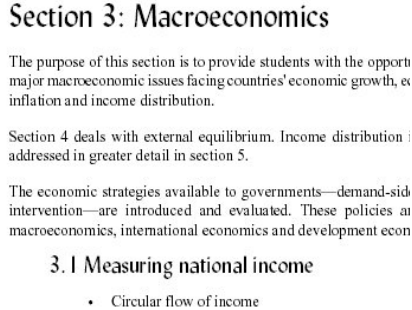
XML as an Encoding Mechanism

First, XML was used as an encoding mechanism to structure and manipulate information. It was not designed as a programming language; rather, it was developed to improve the way computers generate data, read data, and ensure that the data structure is unambiguous and more stable. So, XML provided a set of rules, guidelines, and conventions for designing text formats that enabled the structuring of data.

Using XML to Divorce Display From Content

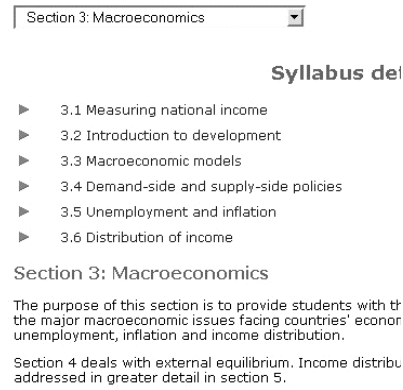
XML was useful for storing information that needed to be presented in a variety of formats. Using XML, it was possible to divorce display from content using separate style-sheets. As previously mentioned, the same source of content used for the printing process was used for the Web; however, both outputs used their own XSLT so that they looked and functioned differently. Figure 1 offers a visual comparison between the printed and online versions of the same source of content:

Printed Version



(IBO,2003a)

Online Version



(IBO,2003b)

Figure 1. Divorcing display from content—printed and online outputs from one source

Cascading Style-Sheets (CSS) were used with the Subject Guide's XML file to turn its XML tags into layout instructions (specifying the fonts, backgrounds, colours, etc.). An instruction was written into the XML file specifying how it should use the CSS file to define the way web browsers displayed the file online. Changing the whole look of the Subject Guide only required a change to the CSS file, rather than to the whole document. If another website was going to display the Subject Guide, they could, in theory, apply their own CSS file to the file to make it look more consistent with their own website (the IBO uses a number of websites for different purposes and audiences). Using XML, it became possible to also specify that only parts of the Guide appear on certain websites. Selective versions of the Guide could be created dynamically on demand in response to a user's / website's request. The content could then appear differently on various IBO and external websites, customised to the needs of their respective users and according to the design motif adopted by the respective websites.

If required, XML could in future also be used for multi-channel display systems because it can be converted to a variety of different display formats, such as interactive television, PDAs, and mobile phones. HTML versions of content can be made more accessible to users with physical impairments and other special learning needs. The same source of content could be made available to speech-based applications, Braille, Wireless Markup Language (WML) for mobile devices, by writing another XSLT transformation to convert the source to the required output. XML can, in principle, be used to serve different clients using a "one size fits all" system (Bradbury, 2001).

The capabilities of using XML to drive a single source publishing process are summarised in Figure 2, which has been adapted from a digital publishing schematic referred to as "centralised content aggregation" (Merceica, 2001, (p. 81). Figure 2 shows how a single source of content can be used across multiple outputs using XML:

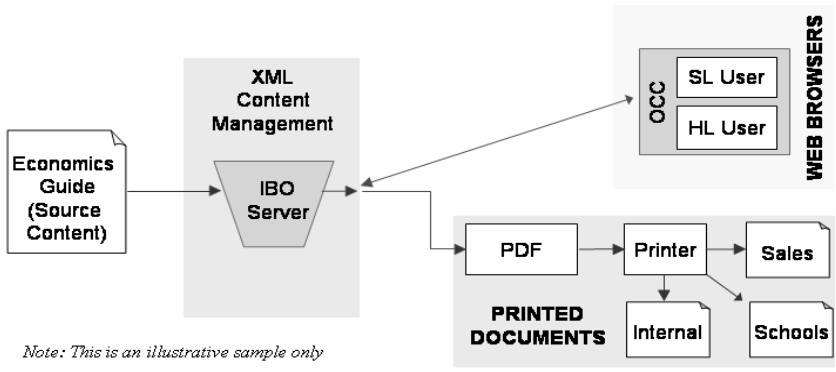


Figure 2. An example of single source publishing

XML as an Open Standard

As a standard for open information interchange, using XML meant that the organisation did not have to be overly dependent on commercially developed proprietary, closed standards that can be extremely expensive. (By extension, XSLT and XSL-FO are based on open standards.) XML can be authored using any basic word processing package, reducing the need to depend on specific vendors or software. Nevertheless, it was still necessary in this case to use PDF, a widely adopted page description language that remains controlled by Adobe Systems.

XML as a Storage Medium

Although the Guide was originally mastered in MS Word, the source XML "version" could then be used as the data-storage medium from then on. A challenge for many organisations collecting large amounts of information is maintaining content. XML is useful for content management, because it can be used to tag data for customised storage (Bradbury, 2001). It is possible to store all sorts of information about a data item or learning object within its XML file.

Limitations of XML

Adopting XML involved an extensive process of implementation. As shown from the basic steps described earlier, the process of preparing content in XML was quite complex. The initial outlay of human resources and finances for this project was considerable, not only because of the new technical requirements for XML, but also because development of the online interactive Economics Subject Guide represented a radical departure from conventional processes and workflows. Extensive in-house and external training was required in handling content markup in XML. The OCC web developer and staff responsible for print-based publication needed to undertake training in XML and XSLT, as well as in new software packages, such as YAWC and XMetaL. An external consultant was also required to assist development and implementation of XML. Familiarisation with the basic standards of XML was required by all of those involved in the process.

A lot of work was required to develop XML elements within the scheme of data management and formatting of the Subject Guide. Deciding which content was generic required careful consideration (i.e., determining which content would be common to all output versions of the Guide). As a corollary of this, considerable effort was required in determining the "granularity," or level of detail to which the content should be tagged. Creating a customised language for the encoding, storage, and display of data created new demands, as it was necessary to keep track of the variants in language and how they work. For these languages to work, those involved in the production/delivery of educational content had to implement the languages describing this content according to a common standard (which was not entirely bad, in that it compelled all of those involved to work towards adopting common standards for the storage, presentation, and dissemination of information, as is discussed in further detail next.)

XML publishing placed necessary constraints on the authoring process to ensure that documents conform to a set structure. On the one hand, these restrictions enforced uniformity in the construction of a document, so that authors could (in theory) concentrate on the content and structure rather than presentation (which was left to a style-sheet). On the other hand, there was a valid concern that adopting an overly structured approach may constrain the scope within which authors could write and develop the meaningful architecture of the Guide.

Another problem encountered at the delivery stage was that XML was not recognised by some web-browsers. At the time, browsers such as Internet Explorer displayed the Guide; however, older browsers such as Netscape 4 were unable to effectively process the XML, displaying the data as seemingly garbled strings of text. XML handling techniques were not always user-friendly. As previously mentioned, a web-browser will reject an XML file if it is not well-formed. For example, failure to put closing tags around a single piece of information resulted in the Guide appearing incorrectly in the end-user's browser.

Accessibility was a critical issue. OCC users accessed the Web from a range of sites (home, classroom, staff room) by way of a range of browsers and modem connection speeds. For this reason, the content of the Guide needed to be fast; however, there were problems when web-users requested content from the Guide in a PDF format to print from work or home. FOP tended to slow the process of delivery. The process had to be refined for usability to increase the speed of PDF files produced "on the fly" (i.e., the PDF file was automatically spawned from the server) or retrieved from a cache.

Further technical challenges emerged when seeking to integrate XML with the broader IBO network. At the time of implementation, there was a lack of support on server, browser, and development tool sides.

BENEFITS OF XML

A key strength of using XML in a single source approach was to reduce the duplication of labour and data. Rather than modify the print and web versions of the Guide separately, it was possible to edit and manipulate one source of content within that document. Specific tags and metadata were used to break the Guide up into modules or "learning objects" that were easier to update on a regular basis. Once the generic content was identified it was possible to automate its dissemination. For example, all Diploma Programme Guides featured the same standard introduction and copyright page. In the future, these sections of the Guide would only need to be marked-up once and automatically generated in all Guides for both the Web and print as necessary. Using a single source in this way avoided unnecessary duplication of content. Because the basic content was the same for both versions, future amendments revisions would (in theory at least) only need

to be made once. Storing all content in a single source meant that there was no longer a need to store this content separately in different media. Different versions could be created as necessary through specific style-sheets.

The systemic approach required for XML to work effectively compelled the creation of standards for the storage and presentation of content across the authoring, designing, formatting, and deliver stages of content creation, which promoted a consistent approach.

Aside from longer-term saving of human resources, the need to find more inexpensive and environmentally friendly ways of disseminating information was an important consideration and driver of web-based delivery. Given the large quantity of data on the OCC, which occupied space on the server and consumed energy, XML was an appealing system.

XML was particularly useful for divorcing the display from the content when delivering data by way of the Web. By looking at the relevant XML tags, a back-end application could manipulate data in different ways (e.g., see Figure 1; Bradbury, 2001). The print version was provided for teachers to reference as a linear outline of the syllabus, while the online version enabled teachers to access this content strategically using a variety of navigational paths, as well as access extra resources.

Another benefit of XML was "future-proofing" the content of the Guide against technological and organisational change. Because XML is useful for storing information that will be presented in a variety of formats, it can be useful as an intermediate step while transforming from one format to another. During the last few years, XML has become widely adopted as data interchange format in areas such as digital publishing (Kasdorf, 2003, p. 86). XML can be converted to other formats relatively easily, so that even if XML becomes obsolete, the source file for the Guide could, in principle, be converted to the new standard for printing and/or the Web. Given that web-based technology changes so rapidly, this ability to future-proof data storage and handling will undoubtedly be beneficial in the longer term.

Perhaps the greatest benefit arose from the conceptual and educational challenges arising from the need to rethink how the content of the Guide could be restructured for the Web. Devising the structure of the content for the OCC website compelled reflection on some of the basic principles of educational design for the Web. Educational needs drove technological

change. The basic educational and design principles underlying this approach to the Guide will be familiar to practitioners of e-learning and web-design (Collis, 1999; Krug, 2000; Collis & Moonen, 2001; Sorenson, 2002). XML was implemented as a foundation to the development of online content as learning objects to be reassembled and reused in a variety of ways. Implicit in this educational approach was a model of learning according to which the process of accessing and using teaching and learning resources on the Web was viewed as a key part of the process of knowledge formation itself. Essentially, the development and use of web-based resources was understood as a process in which data is converted to information, and information converted into knowledge. The presentation of the Guide was structured according to the principle that the *process* of interacting with the Subject Guide should help the teacher to obtain and make sense of the information she/he needs in both practical and conceptual ways. One of the major benefits of XML is that it can improve the functionality of content by making it both more searchable and customisable (Wollowski, 2002).

For the Economics Guide, content producers were challenged to rethink the online structure and presentation of the Guide in terms of: (a) information hierarchy (i.e., how information is organised); (b) navigation (i.e., how users work their way through content); and (c) design and interface (i.e., how content looked online). Categorising and prioritising information within the Guide was a critical step to developing a blueprint for how it would be delivered online. This stage of development commenced with a logical breakdown of the Subject Guide into its constituent chapters, followed by an exploration of thematic links between and within those parts. Essentially, the Subject Guide was broken into learning objects that could be arranged and rearranged according to the needs of the user. For example, the area of "Development Economics" was a discrete section of the printed version of the Economics Guide, but was mentioned throughout the Guide as a recurring theme as well. The intention was to enable the user to access all of the information about Development Economics directly from the single source in no more than three mouse-clicks. But it was also necessary to limit the degree of "chunking" of information as too many chunks became difficult to mark up and manage. Following the methodology outlined, these "chunks" were therefore prioritised according to: (a) which ones should be given more prominence on screen; (b) which information had to be seen by the user; and (c) which could be optionally viewed. The structure for chunking information was identified to enable flexibility as to how these could be maintained by content providers, and accessed and displayed

onscreen by users. Where certain categories were considered of equal importance, then the design of the user-interface was critical to visually organising this information on screen efficiently and effectively without overloading the user[8].

Consequently, the authors of the Economics Guide were invited to rethink how they could develop the structure of curriculum beyond a conventionally linear, static printed document as a dynamic, organic body of learning objects that can be interconnected and presented in a variety of ways. Authors were invited to adopt a more spatial approach to curriculum development for the Web, which brought about fresh, new thinking and challenges. For example, in rethinking how the structure of the Economics Subject Guide could be redeveloped for the Web, the introduction of XML compelled content authors to reflect on questions, such as: How can the authors of curriculum imagine content differently? What can be done online that is not done through other media, such as paper? How can the Web be used to extend/deepen understanding of the subject area? How are end-users expected to use the content? Are they expected to upload their own resources, download resources (such as PDF versions of the Guide)? Engage problem-solving activities or simply glean information?

Standard printed content that was previously designed in a static and conventionally linear "narrative" was explored as a nonlinear space, whose structure was visualised as a three-dimensional mezzanine in which content is dynamic, interrelated, and shaped by the collective efforts of content producers and users, as opposed to a typical printed guide, which when imagined as a space, had a linear structure consisting of a corridor (the contents-page of the Guide) leading to several separate and distinct rooms (chapters within the Guide).

Development of the online version of the Economics Guide also stimulated reflection upon how the Guide could be more interactive. The web version of the Guide enabled a high degree of user control over the exploration of the subject area online. Rather than bombard teachers with information that may be irrelevant to their interests and needs, the online version of the Guide was flexibly structured to be customisable by end-users, to empower them to seek and discover information of most interest and relevance. Throughout the process of the development of the Subject Guide, it was important that the authors and other producers of educational content remained focused on the core benefits of XML, to drive the printing and

online delivery of content to add value to existing conventional practices (e.g., in print).

Authors were further encouraged to begin reflecting on what kind of common vocabulary (i.e., ontology) may be necessary to express more subjective information, such as the learning objectives of the Guide as an online resource. Determining this ontology is a major challenge experienced by other educational institutions seeking to exploit XML (Saini, 2003).

As a result of this approach, content became more "web-friendly" and more easily managed and updated. By maintaining only one source of content, the Subject Guide could be updated regularly and be more directly responsive to the needs of the user. In summary, the process of reflection stimulated by a single source approach using XML promoted a more organic approach to content development, shifting the use of the Web from a means of disseminating informational data, to thinking about online educational content as a virtual space of living, breathing knowledge.

XML was used in this pilot study to enable the basic architecture for knowledge management so that Subject Guides could become more flexible in their delivery and use by teachers. The vision behind this pilot approach was that, in future, the delivery and use of curriculum resources could be adapted by teachers according to their pedagogical insights and needs across different settings and learning environments. As such, the development of this online approach was not only to supplement conventional curriculum forms and established teaching pedagogies, but also to open up opportunities for new curriculum forms that can be adapted and improved by teachers themselves.

CONCLUSION

Once the Subject Guide for Economics went live on the OCC, the basic framework was in place to expand development of the framework to publishing and repurposing other curriculum materials and resources (e.g., Maths Guides). The DTD written for the Economics Guide could be applied to a range of similar documents (i.e., other Subject Guides) featuring a similar structure.

Since then, the range of XML tools, vocabularies, parsers, and published DTDs has grown. Consequently, the use of XML by the IBO has changed considerably. Certain applications were abandoned due to instability and usability issues. New tools and applications have since been trialled, such as *upCast* to streamline the use of MS Word to author XML documents and *oXygen* to edit XML. Refinement and improvements in the technology have impacted upon workflows.

XML was adopted because it is extensible, platform-independent and supports internationalisation and localisation by enabling the same content to be manipulated according to the different needs of users. As XML uses text, any platform that can handle text could, in principle, handle XML. The XML standard was free to access and enabled the possibility for powerful data management. Establishing the basic architecture for XML opened the way for more sophisticated use of metadata, a reduction in the duplication of human resources and enhanced online display and interactivity of content across different sites of delivery. There were also educational benefits consistent with the use of educational content in database driven approaches to e-learning.

The most visible benefits of adopting XML in the manner described in this article were long term rather immediate. This approach would appear to work best on content that is intended for delivery on a large scale, and the process was not easy! Despite Kasdorf's (2003) assertion that XML could be used on projects as small as a single book or journal, it is strongly recommended to educators that XML may be inappropriate for "one-off" or small projects. Furthermore, XML will not work if generic standards are not adopted for the mass dissemination of content.

The true value of the Economics Guide pilot will be determined once the processes of data storage, handling and thinking about content as learning objects are applied across other subject areas within the IBO. The use of this kind of system requires a close collaboration between educational authors, designers, and ICT technical support. But in the case of the Economics Guide, this collaborative process of rethinking how content was stored and delivered was every bit as rewarding as the outcome or any other technical benefits XML had to offer.

References

Apache Software Foundation (2006). "FOP," *The Apache XML Site*. Retrieved June 20, 2006, from http://xml.apache.org/fop/

Berners-Lee, T., Hendler, J., & Lassila, O. (2001). The semantic web. *Scientific American, 284*(5), 29-37.

Bosak, J., & Bray, T. (1999). "XML and the second-generation Web." *Scientific American, 280*(5), 89-93.

Biz/ed (2004). Biz/ed Website. Retrieved June 26, 2006, from http://www.bized.ac.uk/

Bradbury, D. (2001, December). How XML will change your life. *Create Magazine*, 70-72.

Bray, T., Paoli, J., Sperberg-McQueen, C. M., Maler, E., Yergeau, F., & Cowan, J. (2004, February 4). Extensible markup language (XML) 1.1. W3C Recommendation Retrieved November 10, 2005, from http://www.w3.org/TR/2004/REC-xml11-20040204/

Clark, J. (1999). XSL transformations (XSLT) Version 1.0. W3C Recommendation 16 November 1999. Retrieved November 10, 2005, from http://www.w3.org/TR/xslt

Collis, B. (1999). Designing for differences: Cultural issues in the design of www-based course-support sites. *British Journal of Educational Technology*, *30*(3), 201-215.

Collis, B., & Moonen, J. (2001). *Flexible learning in a digital world*. London: Kogan Page.

Holman, K.G. (2000, August 16). *What is XSLT*? Retrieved 11 November 11, 2005, from http://www.xml.com/pub/a/2000/08/holman/

International Baccalaureate Organisation ([IBO]; 2004). *International Baccalaureate Organisation*. Retrieved July 15, 2004, from http://www.ibo.org

International Baccalaureate Organisation ([IBO]; 2003a). *Economics guide*. United Kingdom: International Baccalaureate Organisation.

International Baccalaureate Organisation ([IBO]; 2003b). *Economics guide*. Online curriculum centre. International Baccalaureate Organisation. Retrieved April 10, 2003, from http://online.ibo.org

Kasdorf, W.E. (2003). Markup: XML & related technologies. In W.E. Kasdorf (Ed.), *The Columbia guide to digital publishing*. New York: Columbia University Press

Krug, S. (2000). *Don't make me think: Common sense approach to web usability*. Indianapolis, IN: New Riders Publishing.

Merceica, P. (2001). Digital publishing: The current state of play. In B. Cope & D. Mason (Eds.), *Creator to consumer in a digital age: Australian book production in transition*. Altona, Victoria, Australia: Common Ground Publishing.

Saini, P. (2003, October). Role of XML in building ontology(s) for e-learning domain. In G. Richards (Ed.), *Proceedings of World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2003* (pp. 132-135), Phoenix, AZ. Chesapeake, VA: Association for the Advancement of Computing in Education.

Salminen, A. (2005). Building digital government by XML. In R. H. Sprague, Jr. (Ed.), *Proceedings of the Thirty-Eighth Hawaii International Conference on System Sciences*. Los Alamitos, CA: IEEE Computer Society. Retrieved August 1, 2007, from http://www.cs.jyu.fi/~airi/papers/HICSS-2005.pdf

Sorenson, N. (2002, January). Six criteria for evaluating your web site. *The Editorial Eye*, (p. 8).

Wollowski, M. (2002, October). Xml based course websites. In G. Richards (Ed.), *Proceedings of World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2002* (pp. 1043-1048), Montreal, QC, Canada. Chesapeake, VA: Association for the Advancement of Computing in Education.

World Wide Web Consortium (W3C). (2003). Retrieved June 20, 2006, from http://www.w3.org/XML/

W3Schools (2004). *XML Tutorial*. Retrieved 20 June 2006 from http://www.w3schools.com/default.asp

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Notes

1. Founded in 1968, the International Baccalaureate Organisation (IBO) is a nonprofit educational foundation that delivers an internationalised curriculum to children and young people aged 3-19 across three programmes: the Diploma Programme, the Middle Years Programme and the Primary Years Programme. As of July 2004, 1,381 authorised IB schools offered a total of 1,634 IB programmes in 117 countries to approximately 200,000 students (IBO, 2004).

2. The IB Diploma Programme is a preuniversity course of study that leads to examinations designed for secondary school students aged 16 to 19. The Programme, which incorporates elements of national systems, is a two-year international curriculum available in English, French, and Spanish, that generally allows students to fulfil the requirements of their national or state education systems.

3. The term "content" is used here to include all text, illustrative, and audio-visual materials delivered by printed hardcopy and the Web, such as Subject Guides, teaching support materials, and general educational resources.

4. The acronym *XML* not only refers to the language itself, but also to a whole family of standards that have developed around it, such as XSL, which is outlined next (Kasdorf, 2003, p. 88).

5. For example, the tag for content relevant to Higher Level (HL) teachers of IB Economics, was: section role="hl." For sections of the Guide relevant to both Higher Level and Standard Level (SL) teachers, the tag defined this portion of content as: section role="hl,sl." These tags enabled manipulation of how Higher and Standard Level content appeared online. A Higher Level section of the Guide could, for example, appear as highlighted text for users logged into the website as Higher Level Economics teachers.

6. YAWC (Yet Another Word Converter) is a plug-in for Microsoft Word that enables Word documents to be converted into HTML or XML.

7. FOP stands for Formatting Objects Processor. See Apache's (2006) website for more information. This process for Extensible Style-sheet

Language Formatting Objects (XSL-FO) provided a way of creating paginated print versions of data stored in XML documents. XSL-FO is a page description language which tells a formatter how to structure text on a page (e.g., specifying size of margins). The source XML document was transformed into FO using a style-sheet and then rendered as a file format suitable for printing, such as PostScript and PDF (Kasdorf, 2003).

8. The rule of navigation, for example, was that the content for the online version of the Guide had to be structured in such a way that the user could access the necessary information within three clicks (unless the content require some form of extended problem solving or interpretative exercise).