ASTRONOMY EDUCATION FOR THE PUBLIC VIA WEB TECHNOLOGIES. FROM THE E-LIBRARY, THROUGH THE E-CLASSROOM, TOWARDS THE E-FACILITATOR

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Abstract

Astronomy, through both the allure of the sky and popular culture, enjoys significant penetration into the public and especially the young. Furthermore, the interdisciplinary character of the field makes it an ideal avenue for teaching basic scientific principles in a context that is both relevant to the subject and interesting to the learners. Nevertheless, communicating astronomy to the public presents certain significant challenges: (a) highly specialized scientific knowledge needs to be disseminated to an audience of a disperse scientific background, often without extended and/or uniform scientific education and skills; (b) the audience is widely dispersed in age, preferences and goals regarding their pursuit of astronomy knowledge; and (c) the audience, consisting mostly of volunteer adults, has a diverse daily time-schedule while scattered over a region considerably larger than a university campus. Most importantly, considering the amateur, sideline nature of public astronomy education, the whole educational procedure needs to be a leisure activity rather than formal learning. Thus in contemporary physical science and astronomy education, educational programs increasingly include problem-based learning and other small group instructional models, collaborative organizations to support student-faculty interactions, and technology-enhanced educational tools. This paper seeks to propose new ways of engaging emerging web technologies to support self-directed, experiential astronomy education for the public. While the collaborative e-classroom is a reality even for the educational activities at a regional Amateur Astronomy Club, prospects exist for a more radical paradigm shift. The semantic Web, with natural language search, recommendation agents and other emerging artificial intelligence tools emphasize machine facilitated understanding of the available information, further streamlining the role of the collaborating facilitator in a problem based learning scenario. Furthermore microformats, modular applications and ubiquitous connectivity for the first time provide a platform that can really claim to offer a fully realized learning experience, available anytime, everywhere.

Keywords
Web 2.0, Web 3.0, active learning, problem based learning, e-learning, astronomy

1. INTRODUCTION

Astronomy, as a scientific field, is probably the field of knowledge that any person would like to know more about. The alluring connotations of the starry night and the proliferation of astronomical snippets in science fiction and popular culture generate in everyone at least a passing curiosity for the subject. This fact along with the interdisciplinary character of the field, makes astronomy an ideal avenue for teaching basic scientific principles in a context that is both relevant to the subject and interesting to the learners.

Communicating basic science to the public presents certain additional significant challenges:

(a) highly specialized scientific knowledge is disseminated to an audience of a disperse scientific background, often without extended and/or uniform scientific education and skills;

(b) the audience is of a wide age range, preferences and goals regarding their pursuit of scientific knowledge; and

(c) the audience has a diverse daily time-schedule while scattered over a region considerably larger than a university campus.

Most importantly, considering the amateur, sideline nature of public science/astronomy education, the whole educational procedure ought to be more of a leisure activity rather than formal learning.

In order to accommodate such requirements, contemporary education is embracing tools and approaches from two different fields. On one hand, alternative educational approaches have long been introduced in science education. These include integrative curricula delivered via active, self-directed, student-centered, experiential learning. One the other hand, information technologies are also being employed to harness information explosion and support teaching in various ways. Ultimately, these two different fields could join their contribution, with information technology effectively supporting active learning.

Traditional education requires students to sit through hours of lectures and discussion takes place in large groups, sometimes with the whole class present. Advances in our understanding of learning processes now suggest that such techniques may be suboptimal, and that learning should evolve from learning by acquisition to learning by participation. New approaches build on concepts of active learning, defined as the process of having students engage in some activity that makes them reflect upon ideas and how they are using these ideas. Such new educational approaches require students to regularly assess their skills and knowledge at handling real world problems. Some student centred, active learning approaches include problem-based or case-based learning, inquiry and discovery based learning, role and game playing based learning, as well as collaborative and interactive learning of all kinds. Such approaches rely on situational learning and are active, self-directed, student-centered, and experiential [1]. In such educational approaches learning typically involves small student groups, in which the participants actively work with reality-based situations to formulate problems and learning needs that will guide their further studies. The teacher’s role is that of facilitating learning rather than transferring knowledge [2].

This evolving shift from ‘teaching’ to ‘learning’ in contemporary education is also strongly related to an increasing involvement of information and communication technology. There is currently an international trend to involve computers and the Internet in formal education as well in continuing life-long learning. It is possible to identify three generations of information technology supported learning, which usually come under the collective term of “e-learning” (literally translated as “electronic learning”) [3]. The first generation is based on multimedia technology support, such as videos, CD-ROMs or other stand-alone educational software. The second generation employs telematic technologies and it is basically set up as teaching via the Web, where conventional educational material, as well as entire educational courses, are delivered via the network to remote students. The last, emerging generation, is about web based learning, where the network is used as a means to create active, context based, personalized learning experiences. This last generation of e-learning shifts the emphasis from ‘teaching’ to ‘learning’ and from the notion of technology as a didactic mediator to the notion of sociable, peer-supported, involved learner. The knowledge repository of the Web can help the students defend their choices and standpoints while the connectivity offered by it can be utilized to discuss and develop problem-processing skills, self-directed learning skills and group competence.

It is the scope of this work to explore first the legacy of Web 1.0 as an astronomic educational tool and then describe the present current utilization of Web 2.0 in contemporary astronomy education in order to accurately assess and try to extrapolate the potential opportunities present in the emerging Web 3.0 paradigm.

2. THE FIRST STEPS: WEB 1.0 AS A VIRTUAL DIGITAL LIBRARY

A significant hurdle in astronomy education, especially to people of non scientific background (either young students or interested adults), is the distance of the subject from any common perception or reference. This is, after all, the main reason for which most of the public has several naively justified but non-scientific misconceptions about the subject [4]. First of all the learners must visualize non-trivial 3 dimensional information (like planets' and stars' trajectories). Secondly, the magnitude of distances to other planets, stars, or galaxies lacks any connection to personal experience and finally the time dependant nature of astronomical phenomena requires not just the understanding of spatial positions and orientations, but how these change over time. Computer 3D modelling and visualizations come to address all these challenges. These systems give the user the ability to interactively change the frame of reference, looking both from the outside of a 3D simulation and immersed in it. Additionally they offer the ability to change the scale of view in order to showcase different scales and lastly present the user with the capability to observe interactive real time motion of the virtual environment [5].

With the advent of multimedia and enhanced visualization tools came the proliferation of the fledgling Web. Its inventors cite Vannevar Bush's idea of extending one's intellect "…by making their collective knowledge available to each individual by using machines." [6]. The network infrastructure, data model, and architecture of the Web led to the creation of a huge repository of humanly readable knowledge interlinked by a multitude of alternative pathways [7].

Of major importance is the potential of hypertext technology to provide interconnected pieces information, and link questions with explanations within the wider scope of a particular educational task. Supporting the dissemination of information is its easiest and most straightforward achievement. The Web has extensively and successfully been used to give quick, easy and cheap access to information sources, such as books, textbooks, atlases, astrophysical databases, research journals etc. Specific astronomical repositories were promptly created in the Web. For example, NASA's Astrophysics Data Systems (ADS) [8] and the NCSA Astronomy Digital Image Library [9] quickly developed and evolved as fully web-enabled digital libraries. Additionally, the Web has been used as a worldwide astronomy laboratory, giving on-line access to specific scientific equipment to perform experiments for teaching in science and astronomy, for example in demonstrating the notion and practice of spectroscopy [10].

Although the Web was seen as a basically static structure with passive viewers, there have been a number of attempts to implement variations of active learning and especially problem-based learning on the Web. It has been argued that computer mediated communication can be used to enhance collaboration and interaction within learner's groups. For example, asynchronous discussion boards give the opportunity to analyze interaction and learning, measuring participation levels and interaction patterns; a comprehensive review of general research and practices in the area is presented in [11].

There also have been implementations where a special software is used to present a single student with a problem, and guide interactively the student through to the solution and towards the acquisition of the respective amount of knowledge and competences [12]. In general, the use of computer as a coach in problem-based learning has been investigated in several set-ups and models, e.g. 2-student groups with help seeking student model, where the program gives help [13]. It is noteworthy that students can use these tutors in groups as well as alone. In many settings, students work together on tutors and discuss issues and possible answers with others in their class.

Another interesting example is that of the Swinburne Astronomy Online (SAO), an international suite of graduate programs of Science in Astronomy with students from over 34 countries. Students are required to post questions and/or extension comments in forums and to attempt to answer to each other's questions. Instructors act as guides, aiding the discussions by contributing extra information and follow-up questions. They intervene in discussion threads that have gone off the rails, but avoid dominating discussions [14].

This initial involvement of the Web to support education was mainly based on the metaphor of a virtual classroom, whereby the web application follows the model of a real classroom transferring there the conventional lecture, discussion, workshop and other educational activities [15]. About a decade ago, a systematic and critical meta-analysis of more than 330 studies by Russell concluded that there is no significant difference between various learning/teaching methods, but the focus is actually the comparison between technology enhanced versus conventional education [16]. Today, it is widely accepted that this is an inappropriate comparison, as the use of technology not only changes the way education is deployed, but has a profound effect in the pedagogy, as it carries a mean by itself. So, nowadays the discussion is about how technology, and the Web in particular, can stimulate a new learning culture. In these terms, to make a difference implies harvesting the potential of learning via the Web to equip the learner with competences rather than mere subject knowledge [17]. And this is where Web 2.0 enters the stage.

3. PARADIGM SHIFT: WEB 2.0 & ACTIVE LEARNING IN ASTRONOMY

The collective term Web 2.0, was originally introduced by O'Reilly in 2004 while he and several other opinion leaders in IT decided to present their vision of the internet's evolution, or revolution [18]. The "version" change was to demonstrate the radical paradigm shift of the internet as a repository of static knowledge to the internet as an interactive platform that everyone can contribute and formulate both, content and applications. It was to become a tool, as its creators put it, for "harnessing collective intelligence".

In Web 2.0 the user is seen as a contributor, rather than a mere recipient. Content is created by participation and collaboration as an emergent product of human (and program) interactions. In the core of Web 2.0 lies an ensemble of standards, protocols, technologies and software development architectures and approaches that enable the seamless communication of third party programs thus creating the communities and networks of services that bring people together. One can argue that a major characteristic of Web 2.0 is the fact that it continually improves and grows in size, function, complexity and approach, thus making the term even more uncertain and difficult to define. Web 2.0 is not a program or an upgrade or a single concrete piece of technology, it is rather a more fully implemented Web. It is based on the same infrastructure and standard protocols, and on well-proven technologies and tools of the Internet and the Web. However, the term Web 2.0 encompasses a whole new meaning and a collective emergent behaviour of the use of these technologies, tools and applications that create networks and communities of users (both humans and programs) that enhance and promote collaboration, sharing, re-use, participation, openness and personalization.

All this emergent behaviour that characterizes Web 2.0 is enabled one way or the other by a variety of applications and tools that form the core of Web 2.0, and by their turn are empowered by an ensemble of technology, embracing both familiar technology from the early days of the Web as well as innovations. Among common Web 2.0 tools that are being explored for their possible use in education are wikis, blogs, podcasts, social networking tools and virtual worlds [19]. Most often Web 2.0 sites combine more than one of the above applications, and have in common a variety of tools and features that enhance participation and collaboration such as search engines, links to other resources, ability for the user to add content and/or comments, tools for organizing content (e.g. tags, extensions by similarity, rating, etc), and signals for updates [20].

A significant feature of this global platform with its core data components is that it can be utilized by anyone and everyone. In Web 2.0 everyone and anyone can contribute content which, due to its provisions is enhanced with user defined tagging information and served on demand to any interested party. That fact alone adds extra value to the contributed content due to its social implications. This content flow back and forth between the various contributors that utilize the same tags (which at times are regionally or culturally loaded terms) create communities or ad hoc common interest groups brought together only by content creation and sharing [18].

In astronomy education and informal astronomy dissemination, there are several examples of Web 2.0 based examples utilizing user collaboration in order to disseminate astronomical knowledge to a wide and diverse audience.

Virtual worlds on the Web are increasingly used to create fluid learning communities who can be engaged in real world didactic situations, collaborate to approach solutions to problems, seek knowledge, and communicate and interact with peers – a comprehensive review is given in [21]. Interactive multiuser virtual environments like Second life have a multitude of astronomically themed educational locales. Specifically, the International Spaceflight Museum [18], JPL's (Jet Propulsion Lab) Explorer Island [22], SL Planetarium [23], SL Science Center [24], Slacker Astronomy [25], NASA Colab [26] and others have a strong presence along with many small telescope models that show limited astronomical imagery. It is interesting to note that NASA Live TV broadcasts into SL at numerous locations for launches or other public programming [27].

Nevertheless, the developed infrastructure of Web 2.0 to “harness collective intelligence” does not always require expensive commercial initiatives. For example, in a regional amateur astronomy club, the authors created a Web 2.0 virtual place for students and instructors to collaborate and explore and create new knowledge in astronomy via problem-based learning sessions [28]. Specific objectives of this work included:

(a) support of collaboration of remote astronomy experts (amateurs and professionals) in order to devise, develop and deploy didactic problems for problem based learning in astronomy;

(b) deployment of problem-based sessions in virtual teams, where both students and instructors may be located in remote places;

(c) support of strong instructor’s presence in a PBL episode;

(d) tools for student inquiry and collaboration; and

(e) provisions for mechanisms for continuous monitoring and evaluation, that would address direct knowledge, as well as tacit competencies targeted via PBL.

In this work, the instructors collaboratively developed a problem in a wiki. Discussion was initiated via a problem’s blog and forum, where students and instructors collaborated to analyze the problem, identified conquered knowledge and planned actions for problem solving. Then students searched (via the Web but not confined to it) and collaborated to solve the case via the wiki. Student activities, progress and more importantly gained experience and competences were recorded, shared and commended on via their personal blogs. The entire learning episode and all its steps (with the final problem/answer deployment) was recorded, commended on and monitored via the wiki (final and intermediate versions) and the participants’ blogs. This project was met with a great deal of enthusiasm from the participants. While all of them evaluated their knowledge of the subject as having improved, the most positive result was that a significant part of the students considered this to be an interesting experience and expressed interest in repeating the process in the future.

While the above mentioned Web 2.0 PBL project was met with success, it did reveal certain limitations imposed in the transition of the educational method to the e-space. First of all, while all the provisions existed for seamless linking of content, through the wiki’s intuitive linking functionality, sometimes there existed the problem of meaningful correlation of the linked content. For example during the development of the course, one student could elaborate on a specific subtopic (e.g. the speed of light) in order to elucidate one aspect of the problem (e.g. astronomical time scales). At the same time, another student could be elaborating on the same subject (again for example the speed of light) useful also in another subtopic of the problem (specifically the definition of the light year, as an astronomical measurement unit of distance).

Then, as it would happen, slight naming changes in the wiki’s entries (e.g. Speed of Light vs Light Speed), so common in students not yet fully familiar with the subject, would create duplicate entries with overlapping but not identical content. It was the facilitators’ job at regular intervals (usually two times each week) to check all of the wiki, consolidate redundant entries and initiate a discussion on the subject to clarify the reason for this change.

This very process revealed another one of the technology’s shortcomings in the transition of the PBL procedure from the classroom to the e-classroom: the problem of asynchronous online communication. The participants often felt that they would be better motivated if they could be contacted when important updates were implemented in the project so that they could schedule their participation more efficiently. Now, wouldn’t it be nice instead of us facilitating the system, the system facilitated our e-learning experience? This is where Web 3.0 steps in.

4. THE ROAD AHEAD: WEB 3.0 AND SEMANTICALLY ENHANCED ASTRONOMY EDUCATION

It is interesting to note that in their seminal paper, the inventors of the Web [7] envisioned a platform that not only "…links between pieces of text (or other media) mimic human association of ideas..." but also allows "…associations to be deduced from the content of text." The interesting part in these quotes is that it took almost 15 years and two revolutions in the Web to bring the information technology's paradigm on par with that vision. After the failure of the concept of a centralized, stand alone "artificial intelligence (AI) program" in the 1990s [29], the proliferation of the Web 2.0, with its ease of adding metadata, ad hoc taxonomies of social groups and free form tagging led to one realization: since people can better organize data according to their needs we need to make machines able to work with humanly organized data instead of the other way around. And the only way to efficiently do that is through transparent aggregation and consumption of the metadata that users provide, not through a central "AI" application, but through a multitude of web based "agents" each fulfilling specific functionality and role.

Nevertheless it is also interesting to note that when once again Tim Berners-Lee was asked about Web 3.0 he described it as [30]"…scalable vector graphics—everything rippling and folding and looking misty—on Web 2.0 and access to a semantic Web integrated across a huge space of data…" while the Eric Schmidt, CEO of Google, elucidated one more important aspect of it [31]: "…the applications are relatively small, the data is in the cloud, the applications can run on any device, PC or mobile phone, the applications are very fast and they're very customizable. Furthermore, the applications are distributed virally: literally by social networks, by email."

The term Web 3.0 is attributed to John Markoff of the New York Times in 2006 [32], referring to Internet-based services that collectively comprise 'the intelligent Web'. The defining characteristics of Web 3.0 are: (a) a semantically enabled Web and (b) the proliferation of that semantic Web beyond the traditional computer, to every technologically enabled aspect of the human life, be it mobile phones or home appliances.

The semantic Web is the web platform in which information is given well-defined, structured, meaning, better enabling computers and people to work in cooperation. It aims to bring structure to the meaningful content of web pages in such a way so that knowledge which was formerly only consumed by the user can be managed and consumed by the web platform. This structure, while universal in definition, is not centrally imposed but instead emerges from the provisions made to the users/contributors who are the only ones responsible for the correct semantic representation of the content they are broadcasting. Additionally, the logic system that creates the relational content of the semantically enabled web platform needs to be universal enough to allow rules from any existing knowledge-representation system to be exported onto the Web. Furthermore, it needs to be flexible enough to allow for inconsistencies but not powerful enough to enable them to be consumed by web based agents.

The universal but decentralized nature of the semantic Web's content structuring and relations requires the utilization of a formal set of relations not between content but between generalized classes of conceptual objects. Taken from philosophy, ontologies and specifically taxonomies are the tools for developing such conceptual frameworks. A taxonomy defines classes of objects and relations among them creating inference rules that can lead to the consumption of the web based content by relevant agents. These agents are the true power of Web 3.0. Decentralized, specific in scope and role and web based they are able to consume the ontological information loaded into web content and utilize it to provide user specific added value to the content broadcasted on the web platform. The power of the Web 3.0's semantic content is exponentially increased when that content can be ubiquitously utilized across technological boundaries. Ontological frameworks describing the classes and the relations of real world objects such as consumer electronics or home appliances, embedded intelligent agents utilizing this information to perform user requested tasks can create a seamless invisible platform of "ambient intelligence" that transparently facilitates productivity or leisure [33].

As can be seen from this very brief overview of the core features of the Web 3.0 notion, this web platform could readily resolve the shortcomings that were previously mentioned. A semantically enabled learning management system could utilize metadata and "e-facilitate" a PBL episode by removing the tedium from both learners and facilitators. Intelligent agents could be utilized to disambiguate content and with the intervention of the facilitators even suggest further resources in order to clarify any possible misconception that led to these ambiguities in the first place. Furthermore ubiquitous connectivity could assist in a truly situational learning experience. Interested learners could subscribe to SMS (i.e. mobile telephony short messaging system) or voice mail services and be informed of related updates so that they can further customize their learning experience.

But, is this, at the moment, nothing more than wishful thinking? Two important technologies for developing the semantic Web are already in place: eXtensible Markup Language (XML) and the Resource Description Framework (RDF). XML provides for ad hoc tagging to create semantic annotations in web pages or sections of text on a page while the Resource Description Framework (RDF) provides a formal way of describing the meaning of these ad hoc metadata in each instance [34]. The XML/RDF framework was the basis for the development in 2004 of the Web Ontology Language (OWL), a language for describing classes of objects (as opposed to specific instances of content objects which is the purview of RDF) and the relations between them [35]. It must be noted that since 2007, OWL undergoes its first major revision and extension incorporating both experiences from its utilization and recent theoretical advances in logic-based knowledge representation [36]. In the e-learning front, semantic conformance profiles are being developed [37] in the context of the reusable learning object concept (RLO) within the framework of the Shareable Content Object Reference Model (SCORM) [38]. In fact, efforts are made to implement such a framework on “Intelligent Learning Management Systems” [39]. These works demonstrate that, while widespread implementation of Web 3.0 LMSs is not yet here, the transition from the e-classroom to the e-facilitation is not very far away.

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