Review

A Website for Astronomy Education and Outreach

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Teach Astronomy is a free, open access website designed for formal and informal learners of astronomy. The site features: an online textbook complete with quiz questions and a glossary; over ten thousand images; a curated collection of the astronomy articles in *Wikipedia*; a complete video lecture course; a video Frequently Asked Questions tool; and other materials provided by content partners. Clustering algorithms and an interactive visual interface allow users to browse related content. This article reviews the features of the website and how it can be used.

Introduction

Increasingly, people turn to the Internet for information. Over 90% of Internet users employ search engines to find information (Purcell et al., 2012) and 65% use the Internet as their primary source of scientific information (National Science Board, 2016). Traditional sources of scientific information such as textbooks written and curated by content experts are languishing as online information sourcing gains popularity, due in large part to the soaring price of printed textbooks (Senack & Donoghue, 2016). The new media landscape forces scientists and educators to find more effective ways to give the public accurate scientific information, on which complex societal issues increasingly depend (Brossard & Scheufele, 2013).

A Google search of the word astronomy returns well over a hundred million results. The most popular websites on astronomy are: those hosting new stories, like *Universe Today*[1] and *Space.com*[2]; those run by organisations that conduct astronomical research, like NASA[3]; or those that cater to amateur astronomers, like the websites *Sky and Telescope*[4] and *Astronomy Magazine*[5] (Jenkins, 2015).

Teach Astronomy[6] was started in 2011 to complement existing online sources of astronomy information and provide astronomy educators, students, adult lifelong learners, and amateur astronomers with high quality multimedia content. Some of the material present on the website is original whilst some is aggregated with the permission of outside parties.

An earlier article described the creation and early evolution of *Teach Astronomy* (Impey et al., 2016). The site has recently undergone complete reconstruction, with a new front end, a new back end, and significant new capabilities.

Site users

Google Analytics data show that the site has now had over a million sessions with more than 750 000 unique users and an average over the past two years of 45 000 unique users and 125 000 page views per week. The history of site visits is shown in Figure 1. Most users are in the USA (62%), followed by Canada (5.8%), the United Kingdom (5.7%), India (3.4%), Australia (3.2%), and the Philippines (3.2%). The site aims to appeal to a mixture of formal and informal learners and in 2017 we implemented a user survey which showed that the largest user groups are students (63%), amateur astronomers (15%), and college instructors (14%). In terms of age, 51% are in the range 18–24, 19% are in the range 25–34, and 19% are in the range 35–54.

Technology

The software behind *Teach Astronomy* was completely reconstructed in 2016. The previous code used Microsoft's web stack; the new code is built entirely on efficient, open source technologies. On the back end, we're using version 7 of a powerful, low-level scripting language called PHP: Hypertext Preprocessor[7], which provides production-level stability while enabling flexibility for the rapid deployment of new features. The backend system is designed to be segmented so that internal developers can build plugins to extend

Figure 1. *Daily visitor sessions to* Teach Astronomy *from early 2011 to late 2016. The data show seasonal dips each summer caused by the large fraction of students using the online textbook in place of a traditional textbook during the academic year.*

functionality and enable new features to be added quickly. With a growing number of visitors reaching the site from mobile devices (usually smartphones, not tablets), the front end is built on Zurb's Foundation[8] using a grid that flexes to automatically fit any screen size larger than 320 pixels through a web standard called media queries.

The newly developed code brought CPU and RAM usage down by almost 90%. This will enable us to add features without worrying about the hardware infrastructure. Such new features include a Content Management System (CMS) for maintainers of the site. We also plan to set up accounts for instructors, so that they can customise the content and the look and feel of the site for their specific purposes.

The most sophisticated technology behind *Teach Astronomy* is a mechanism for the indexing, clustering, and graphical delivery of astronomy content. A set of text-based items is sent to an indexing system called Lucene, by the Apache Foundation[9]. Lucene provides powerful algorithms to search through large collections of semantically related text. It calculates a "distance" between any two items in the index based on keyword overlap, so it is easy to list the "nearest neighbours" to any item. The output of a search and this clustering analysis is a graphical display called a Wikimap. The central node of the Wikimap is the closest match to a search and the nearest neighbours are shown as radial spokes (the default number is ten, for viewing convenience). Clicking on an outlying node centres that item, and a new set of nearest neighbours is displayed. The Wikimap provides an appealing method for browsing or "surfing" related content.

This approach is powerful and flexible. A Lucene index and the subsequent clustering can be created for any text-based content. The obvious application is for articles about astronomy, but images with keyword-rich captions work equally well, and for videos with transcripts the text of the transcripts is clustered. The nodes of the Wikimap are active, so clicking on them can pop up an article, an image, a video, or a URL. The Wikimap runs on HTML5, CSS3, and JavaScript. A full physics engine runs alongside the core renderer, dynamically keeping the nodes evenly spaced.

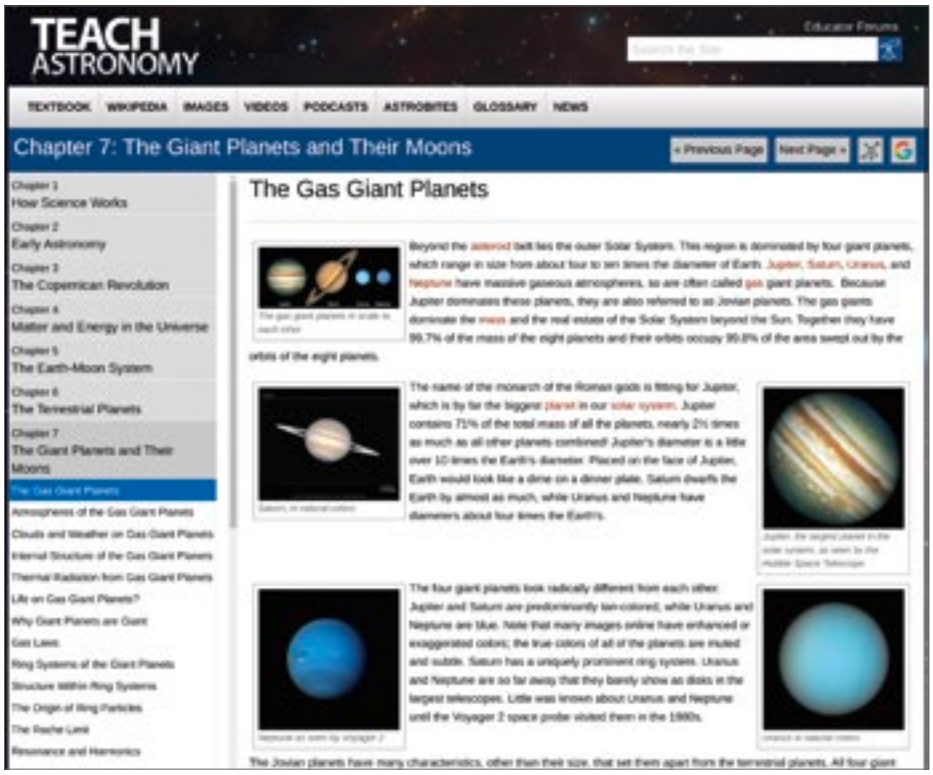

Figure 2. *A textbook article on* Teach Astronomy*, presented in standard chapter order. The open source figures are set in line in a format that adjusts to the web browser, even accommodating handheld devices. Credit: Teach Astronomy*

The most ambitious application of this technology is the curation of content from *Wikipedia*[10]. Astronomy is the testbed but we are extending the application to other subjects. *Wikipedia* is a largely unstructured collection of 5 million articles in English covering almost every topic imaginable, kept current by an army of editors (Mesgari et al., 2014). After capturing the entire set of articles, we use an algorithm called a naïve Bayes classifier. The classifier is given a set of hand-picked articles selected by an astronomy content expert, and a set of randomly chosen articles as a control. It then operates on the entire *Wikipedia* content to divide the articles into two categories: astronomy and non-astronomy. The process produces high completeness for relevant content at the expense of some contamination with unrelated content, but the Lucene indexing and clustering ensures that a user rarely encounters an irrelevant article.

Content

Each type of content on *Teach Astronomy* can be searched by keyword or phrase, and most can also be explored using Lucene clustering and visual display via a Wikimap.

Textbook

The core of *Teach Astronomy* is a set of over 500 articles and 400 000 words covering all topics in astronomy, written at the level of an introductory textbook. The articles are derived from a textbook (Impey and Hartmann, 1999), where figures in the book have been replaced by copyright-free images. The content is updated roughly once a year. The articles can be read in a traditional book order (Figure 2) or "surfed" using the Wikimap. Over 700 glossary terms are linked in the articles with pop-up definitions; the glossary can also be searched alphabetically. There is a quiz tool that draws from 1700 multiple choice questions, based on a search of a topic or a keyword. Articles can be translated into many languages using a Google Translate tool built into the web page.

Wikipedia

A unique component of the website is a walled garden of the astronomy content in the online encyclopaedia *Wikipedia*. The use of this resource for learning has been controversial in academia, but studies show that the science content is generally accurate (Konieczny, 2016; Casebourne et al., 2012). The benefit of *Wikipedia* is the long tail of articles on niche topics, plus the fact that editors keep articles current on topics where there is rapid progress. The naïve Bayes classifier returns over 70 000 astronomy articles, which can be accessed by keyword search and explored using the Wikimap (Figure 3). Every month, the entirety of *Wikipedia* is downloaded and the Lucene astronomy index is updated.

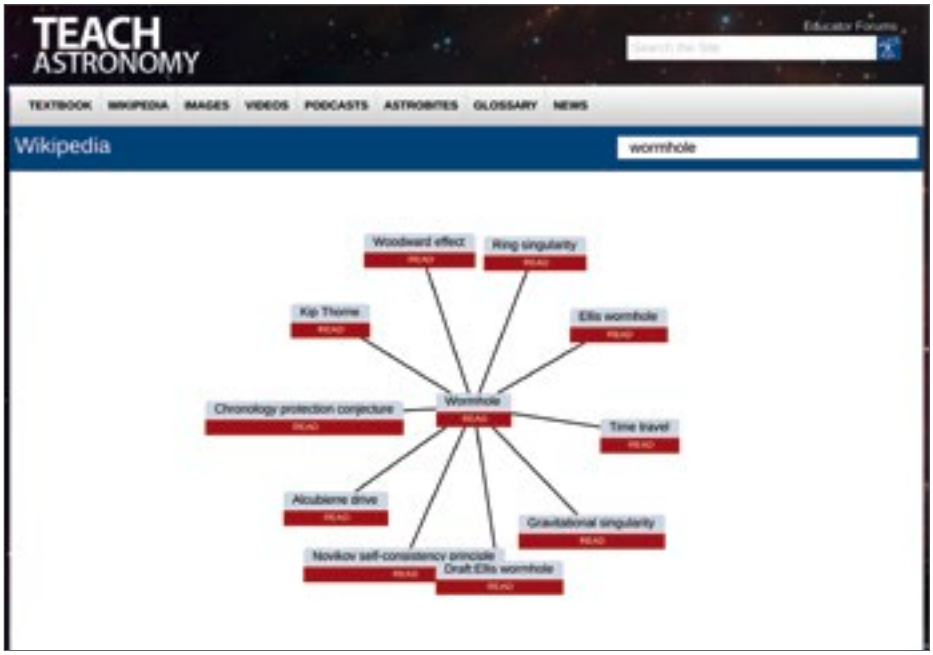

Figure 3. *A Wikimap of the* Wikipedia *content on* Teach Astronomy*, after a search on "black hole". The best-matched article is the central node, and the outliers are the ten most closely related articles based on keyword overlap. Credit: Teach Astronomy*

Images

There are 1200 images built into the online textbook, but *Teach Astronomy* also hosts two other large archives of astronomy images. One is *Astronomy Picture of the Day*[11], which now numbers over 7500 high resolution images. The other is NASA's *AstroPix*[12] which has more than 7100 images from ground- and space-based telescopes. Both image archives have captions with enough keywords to allow effective clustering and exploration with the Wikimap.

Videos

Teach Astronomy has over 1200 short video clips on astronomy subtopics created by the site authors. The videos are of one of the authors filmed on a green screen with astronomical backgrounds inserted. They are organised into 29 playlists on major topics, and taken together they form a complete video course. When accessed, the video clips play on an embedded *YouTube* viewer (Figure 4). They are also available on Apple's iTunes. The videos have transcripts, so can be searched by keyword. They create a thirty-hour video course, or they can be explored using the clustering tool.

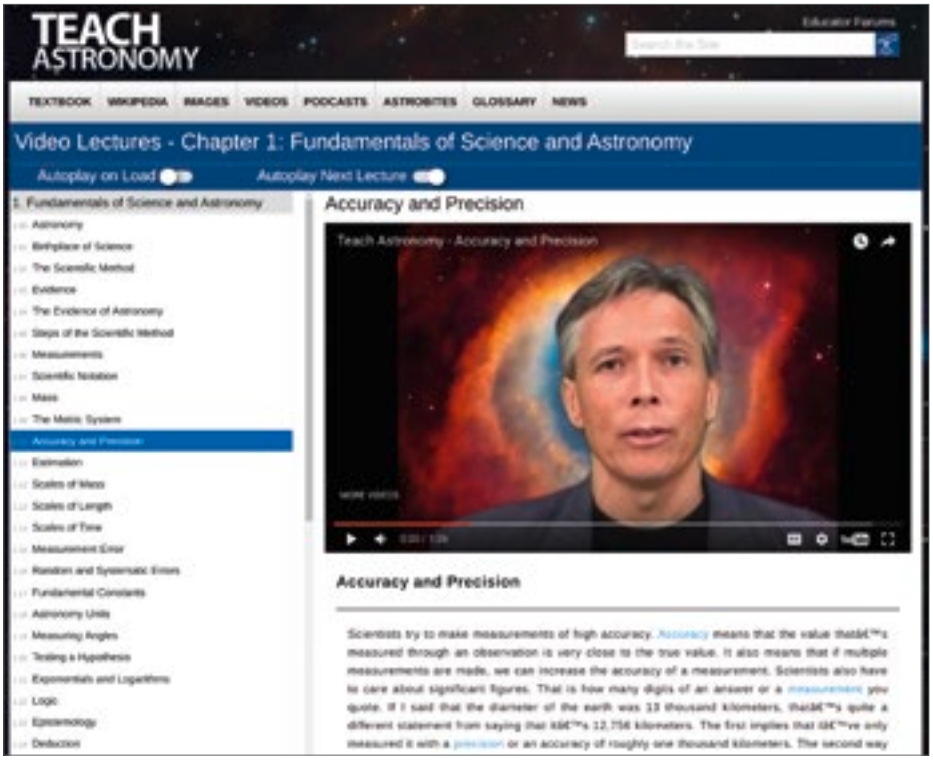

Figure 4. *Screen shot of one of the video lecture clips on* Teach Astronomy*, which can be played on an embedded* YouTube *player. Navigation on the left allows the user to stream an entire video lecture course. Credit: Teach Astronomy*

A new feature of the site utilises live question and answer sessions that we have been conducting for two years for two massive open online classes: Udemy's *Astronomy: State of the Art* and Coursera's *Astronomy: Exploring Space and Time*. Questions on any topic are submitted by *YouTube Live* participants or by email and the video stream is posted every few weeks to *YouTube*. To increase the utility of live sessions, where the questions have no particular topic order, we transcribed the 1200 questions into a database, along

with time tags of their location in the video. Users type questions into a text box and get the closest answers based on keyword match in the database, with the video cued up to play at the appropriate time.

Partner content

By agreement with the curators of *365 Days of Astronomy*[13], *Teach Astronomy* hosts an archive of their 2000 podcasts. Most do not have transcripts, so they cannot be subject to the clustering process. We also host over 1000 summaries of important research papers, written by astronomy graduate students, called AstroBites.[14]. The summaries are suitable for science undergraduates or adults with some technical background. They can be searched by keyword. The final feature is an RSS feed from *Science Daily*[15], which posts three or four items on astronomy every day.

Testimonies

"*I have been using Teach Astronomy in my online introductory astronomy course for non-science majors at two separate institutions (South Florida State College and Florida Keys Community College) for the past four years. Shifting to this open educational resource textbook has been very well received by all my students (approximately 200 per year). I was initially concerned about providing access to the course textbook that is available only online but with rare exception, very few students complained while many of them thanked me for helping to reduce the cost of their education.*" — Erik Christensen, Dean of Applied Sciences and Technologies at South Florida State College. Erik holds engineering degrees from the U.S. Naval Academy and MIT. The main attraction of the site for him and his students is the textbook.

"*There is a need to supplement existing information with more images and videos, web links for additional information, and include wherever possible more references to amateurs, what they have done and what more they could do in the future, especially in terms of providing more information about the use of amateur telescopes and professional-amateur collaborations, past present and future…. I think the site is fabulous. I could spend many enjoyable weeks and months learning from the information you have provided there.*" — Irene Kitzman, a psychiatrist and amateur astronomer who spends much of her spare time at her telescope enjoying the dark skies of Portal, Arizona.

"*An outstanding, comprehensive website! And amazingly, it is free. It will be a great help for the MOOC learners (and the mentors) as they can just be given the link and then find what they are looking for and much, much more. The layout makes it extremely easy to use. It took me back to a time when the World Wide Web was new and searching for one thing led me to site after site exploring further and deeper. For lifelong learners and space enthusiasts it is a veritable treasure trove.*" — Christy Read, who grew up under the dark skies of Indonesia and four years ago discovered MOOCs. She has since taken around forty courses. She has taken about 40 astronomy courses on various platforms.

Notes

1 *Universe Today*: https://www.universetoday.com/

2 *Space.com*: https://www.space.com/

3 NASA: https://www.nasa.gov/

4 *Sky and Telescope*: http://www.skyandtelescope.com/

5 *Astronomy Magazine*: http://www.astronomy.com/

6 *Teach Astronomy*: http://www.teachastronomy.com

7 PHP: http://php.net/manual/en/intro-whatis.php

8 Zurb Foundations: http://foundation.zurb.com/

9 Apache: https://lucene.apache.org/

10 https://en.wikipedia.org/wiki/Main_Page

11 *Astronomy Picture of the Day*: http://apod.nasa.gov

12 *AstroPix*: http://astropix.ipac.caltech.edu

13 *365 Days of Astronomy*: http://365daysofastronomy.org

14 *AstroBites*: http://astrobites.org

15 *Science Daily*: http://sciencedaily.com

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Biographies

Chris Impey is Professor of Astronomy and Associate Dean of Science at the University of Arizona. Winner of eleven national and university teaching awards, he has taught over 100 000 students in two massive open online classes, or MOOCs. He has written over 200 research articles on cosmology, fifty popular articles, and seven books on astronomy topics.

Alexander Danehy is a graduate of the University of Arizona. He has multiple degrees and extensive experience in software development, design, and engineering. He is a web developer and programmer in the Department of Astronomy at the University of Arizona.