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A New Online Astronomy Resource for Education and Outreach

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Abstract

A new web site called *Teach Astronomy* (http://www.teachastronomy.com) has been created to serve astronomy instructors and their students, amateur astronomers, and members of the public interested in astronomy. The content includes an online textbook of 400 000 words and 1200 images, 40 000 articles from *Wikipedia*, over 1100 video clips covering all topics in astronomy, over 6300 images from *Astronomy Picture of the Day* and *AstroPix*, over 1400 podcasts from 365 *Days of Astronomy*, and 25–30 astronomy news stories each week from *Science Daily*. All these resources are navigable by a keyword search and via a unique visual interface called a Wikimap, which presents the items clustered by degree of keyword overlap and allows surfing among related items. The site can serve as a replacement for a textbook and as an information resource for formal and informal learners. Future development includes building an instructor and learner community and creating homework assignments that utilize different content areas within *Teach Astronomy*.

1. INTRODUCTION

Astronomy is well served by the Internet; a Google search for "astronomy" in July 2012 returned over 100×10^6 results. The web sites most frequently visited range from online magazines and blogs to observatories and space missions. The Internet has a lot of information and resources for students and for informal adult learners, but we saw the value in creating a "one-stop-shop" for educational astronomy content. The *Teach Astronomy* site (http://www.teachastronomy.com) fills a unique niche because it offers multimedia materials spanning the entire subject and created by professional astronomers. The core resource is a set of articles derived from the introductory textbook called *The Universe Revealed* by Chris Impey and Bill Hartmann. Additional materials include video clips explaining all topics of astronomy, a set of astronomy encyclopedia articles from *Wikipedia*, images from *Astronomy Picture of the Day*, daily podcasts from 365 *Days of Astronomy*, and an RSS feed of recent Space and Time news articles from *Science Daily*. This paper describes the audience, materials, and the educational uses of *Teach Astronomy*. Figure 1 shows the traffic on the web site during its first year and a half of development.

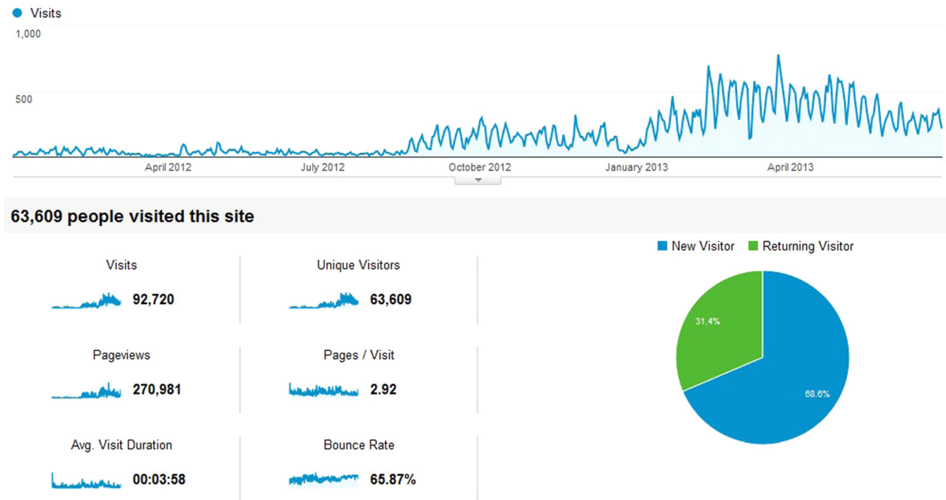


Figure 1. A screen shot from Google Analytics for the *Teach Astronomy* web site shows traffic since January 2012. Each of the over 60 000 visitors has spent an average of four minutes on the site and viewed three different web pages. The site had its first major release in September, 2012

2. TARGET AUDIENCE

The online material collected on *Teach Astronomy* is non-technical, primarily using text and words to convey concepts and information, supported by images and diagrams. Some laws of physics or physical relationships are presented in terms of simple equations, while others are described in words, but the material is in general non-mathematical. The content is, however, pitched at a level that is conceptually challenging and rigorous; no important topic in modern astrophysics is omitted. The goal is to convey the extraordinary insights resulting from empirical and theoretical investigations of all aspects of the physical universe—the Solar System, the life and death of stars, exoplanets, galaxies, and the history and properties of the universe as a whole. Secondary themes that run through the material are how telescopes are used to gather data about astronomical objects and how astronomers do their work by the application of evidence-based reasoning. Since astronomy excites the popular imagination, the web site is aimed at the large segment of the general public that is fascinated by or intrigued by science.

One of the target audiences for *Teach Astronomy* is students taking introductory astronomy courses. Nationwide, astronomy is a popular subject for students taking a General Education or distribution requirement in science if they are non-science majors. The estimate of number of students taking an introductory undergraduate astronomy course a decade ago was 250 000 (Fraknoi 2001) and there has probably been modest growth since then. At the University of Arizona, one in three undergraduates takes one of the astronomy courses for non-science majors. The enrollment number for the 2009 to 2010 academic year at four-year undergraduate programs was 191 000 (AIP 2011). The American Institute of Physics survey does not include students enrolled in introductory astronomy courses at smaller two-year community colleges or four-year programs which do not offer an astronomy degree. The highly dispersed audience is variously estimated to be between 100 000 and 200 000 students (Fraknoi 2001; Waller and Slater 2011). Combining these numbers yields a rough estimate of the number of students taking introductory astronomy courses at somewhere between 300 000 and 400 000. For many of these students, introductory astronomy represents their last formal exposure to science, so this course plays a pivotal role in science literacy, the improvement of which is a major concern of policy makers, educators, and scientists (Impey *et al*. 2011).

For students in a formal instructional setting, the web site can be used as a replacement for a textbook and also as a general resource for astronomy content. A typical astronomy textbook costs $100 (Bruning 2006) and several leading textbooks now cost $140. Faculty in astronomy or physics departments often have resources for instruction, such as laboratory equipment, demos, and small teaching telescopes. *Teach Astronomy* is constantly updated with news stories and podcasts on astronomical discoveries and is a resource where students can learn at any time and any place, reinforcing what is covered in lectures. Faculty at two-year and community colleges often have high teaching loads and poor instructional support; just a quarter have any degree in astronomy so having access to quality content is important (Fraknoi 2004). *Teach Astronomy* has a unique visual tool so that students can discover relationships between astronomy topics easily. Linear layout in a textbook does not let students use this kind of navigation.

Amateur astronomers are another target audience for Teach Astronomy. Estimating the number of amateur astronomers in the United States is difficult, but a range of 200 000 and 500 000 was quoted 15 years ago (Fraknoi 1998). This number most likely has grown with the advent of better and cheaper small telescopes that can be used without any detailed knowledge of the night sky. Another highly engaged new audience for astronomy is the group of people doing citizen science projects like Zooniverse, which numbered 600 000 in early 2012, over half of whom are in the United States. The populations of amateur astronomers and citizen scientists are distinct but overlapping; both possess enough astronomy interest and knowledge to contribute to the research enterprise (Henden 2011). Combined, they number approximately a million, orders of magnitude more than the 7000 current members of the American Astronomical Society (AAS 2010). While amateur astronomers require specialist types of observing information from books, magazines, and of course the Internet, they also benefit from a general knowledge of astronomy to understand the objects of their attention. *Teach Astronomy* has broad coverage that helps to expand the keen amateur astronomer's knowledge base.

Casual and informal learners comprise our last major target audience. Informal learning is non-structured, where someone with any level of interest in a topic learns more about that topic at their own pace. This might be someone who visited a science museum and became interested in volcanoes in the solar system and would like to learn more or someone, whose career path took them away from their childhood hobbies and now they would like to revisit those old interests. *Teach Astronomy*'s navigational tools and rich media content allows any person to easily peruse an astronomy topic and can help informal learners quickly find information they are looking for along with related subject content.

3. USER INTERFACE

The backbone of *Teach Astronomy* is a user interface called the Wikimap. Most collections of information on the Internet use a flat file structure or a simple hierarchical organization. Teach Astronomy does use a traditional list as a familiar means of presenting the online textbook, but the underlying technology keys off text files incorporated into a database. Items are retrieved by a keyword search with the closest match to the title of the item appearing as the central node in the Wikimap, with the next nearest ten items arrayed around the central node like spokes on a wheel in a spiral pattern, where increasing distance means a less close connection to the search term or the central node. The proximity between any two items is based on keyword overlap. If the user clicks on any of the outlying nodes, the Wikimap is redrawn with that node placed at the center and a new set of outlying nodes arranged as before with proximity based on the keyword overlap (Figure 2). For any content item, hovering over it with a mouse gives a pop-up box with the choices of launching the item—showing the text, or playing a video clip or an audio file for a podcast—and of automatically performing a Google search using the search term.

Each of the content types on *Teach Astronomy* functions in a similar way. Multimedia content needs to have a text component to be clustered, so for images the caption is used, and for video clips and podcasts, transcripts are used. Clustering is based on keyword frequencies and overlap, with particular weighting given to title keywords; it is carried out using open source software and customized search algorithms. These clustering algorithms feed search results to the Wikimap, which is a general term for our display, search, and clustering algorithms. The Wikimap display interface is an Adobe® Flash® tool that displays results from a search query spiraling radially

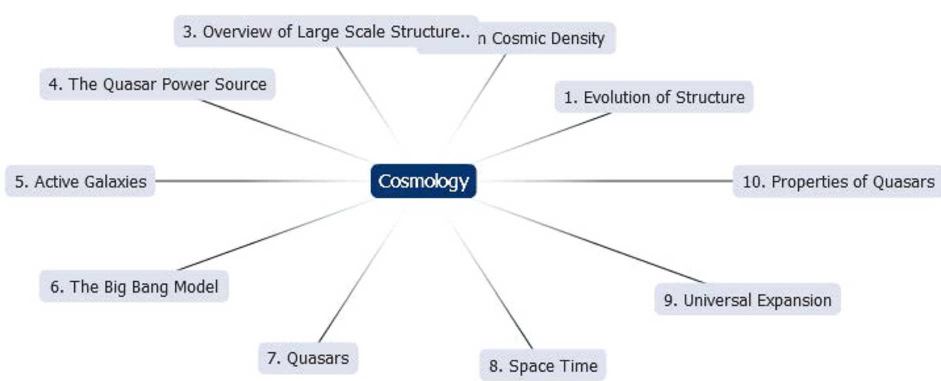


Figure 2. Example of a Wikimap display, where the keyword is cosmology and the content being searched is the set of textbook articles. The clustering algorithm delivers the closest ten articles based on keyword overlap. An article can be selected and read with a click and clicking on an outlying node will center it and retrieve a new set of the ten most closely related articles

outward from a central node, see the example in Figure 2. Information from a search query is gathered using an Apache Lucene™ text search engine library. Users preferring a linear list like those returned in a Google search can switch to "list view" for any content type. The interface for mobile devices is a variation on the desktop list view that accommodates varying screen resolutions, software, or browser compatibility. Social networking is encouraged by buttons allowing a user to share (or "like") pages on Facebook, post them on Twitter, or email them to a colleague or friend.

4. TEACH ASTRONOMY CONTENT

There are six different categories of astronomy content on Teach Astronomy: textbook articles, Wikipedia articles, images, video clips, podcasts, and news stories. More information about each category is given in the following subsections.

4.1. Textbook Articles

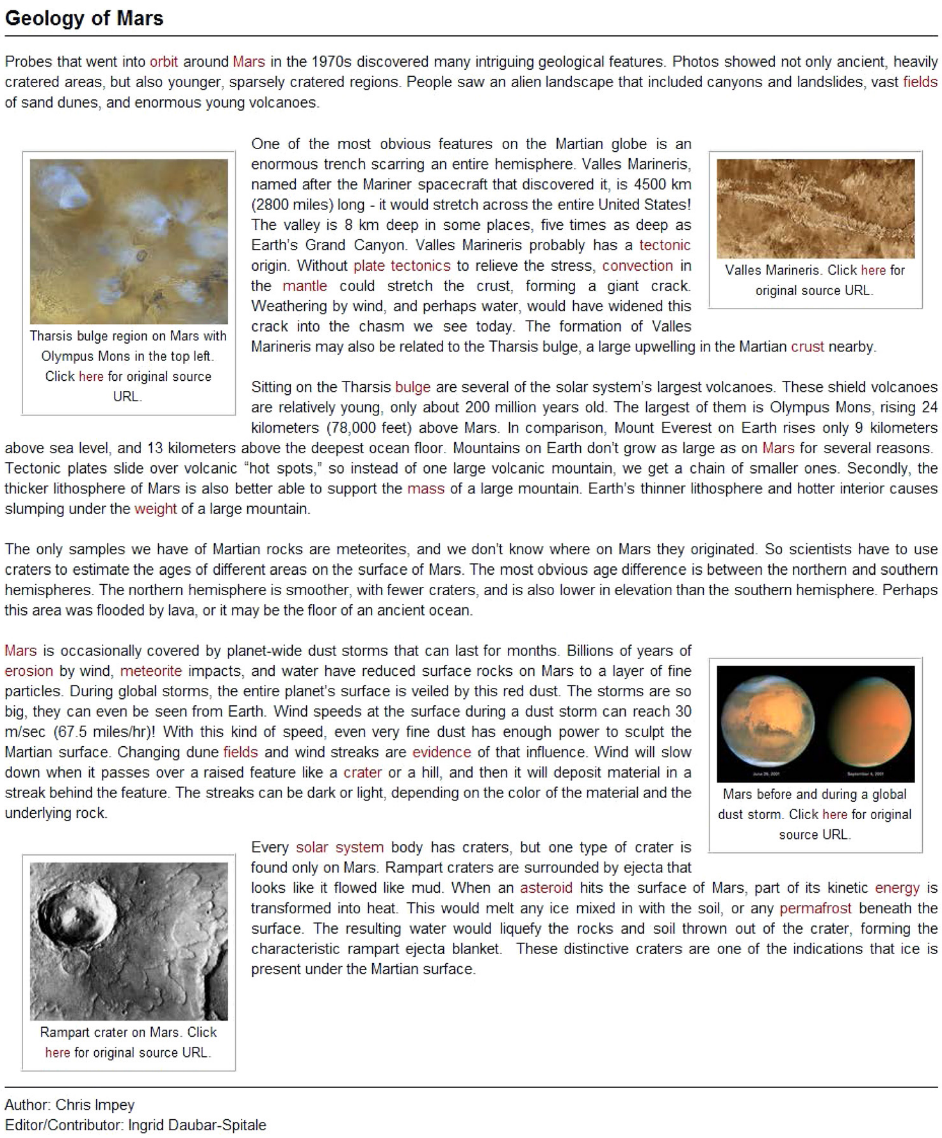
The textbook articles were originally derived from the introductory astronomy textbook *The Universe Revealed* (Impey and Hartmann 2000). The intellectual property was returned to the authors by mutual agreement with the publisher and then transferred to Impey. All graphics that had been created by the publisher and images where permission to publish was only valid for the original printed book were removed. The textbook was broken up into discrete articles, each one corresponding to the scope of a subsection of a chapter in a traditional textbook. These "articles" are updated roughly once a year to reflect progress in astronomy. Diagrams and images for each article were gathered primarily from Wikipedia, and they are either from public domain sources or contain Creative Commons licenses with redistribution attributes. More information about the image licenses can be found in the Terms of Service page for *Teach Astronomy*. There are 380 textbook articles, comprising 400 000 words of text and layered with 1250 images (see example in Figure 3). Articles have keywords hyper-linked to a 620-term glossary, where the definition appears when a user "hovers" the mouse over the term. The online textbook is called *Astropedia*, distinguishing it from the overall resource called *Teach Astronomy*.

Two layouts for viewing textbook articles are available; textbook layout and Wikimap layout. The textbook layout is a linear format that would be seen in a textbook, with topics following a traditional flow, starting with historical material, then covering the Solar System, the Sun and stars, the Milky Way and galaxies, cosmology, and life in the universe. This format is designed to be familiar to students and users who prefer traditional content ordering. At the end of each chapter in the textbook layout, a separate article contains a set of questions that can be used for review or as problem sets. The alternative, Wikimap layout is dynamic and utilizes our search, clustering, and display tools. The clustering algorithms are very reliable applied to these articles, which typically have 500–700 words and are rich in keywords. With the Wikimap layout, a user enters a search term and finds the best matching article, then sees other related articles in one view. The interface allows users to surf and follow connections between topics or articles.

4.2. Wikipedia Articles

Wikipedia is a remarkable phenomenon of the Internet. It forms the world's largest knowledge database, maintained largely by thousands of authors and editors from around the world. Started in 2001, it now has over 4×10^6 articles (http://en.wikipedia.org/wiki/Main_Page). Wikipedia is the most used information source on the Internet (Zickuhr and Rainey 2011), referred to by 62% of the college-age population, aged 18 through 29. Wikipedia has been a lightning rod for criticism in the academic community, but in technical fields, where there is no clear motivation to maliciously alter the content, articles are generally of high quality and accuracy. In fact, the problem is often overly technical writing for any non-expert audience. One study comparing Wikipedia and Encyclopedia Britannica concluded that there was little difference in reliability and accuracy between them (Giles 2005). Since then, the Wikipedia governing body and senior editors have made significant efforts to improve article quality and to counteract vandalism of articles, so the general high quality has been sustained (Lewandowski and Spree 2011).

Inclusion of Wikipedia articles in *Teach Astronomy* does not imply affirmation of their accuracy; as with any encyclopedia resource, users should treat it as a first point of information. Among the astronomy articles on



Geology of Mars

Probes that went into orbit around Mars in the 1970s discovered many intriguing geological features. Photos showed not only ancient, heavily cratered areas, but also younger, sparsely cratered regions. People saw an alien landscape that included canyons and landslides, vast fields of sand dunes, and enormous young volcanoes.

Tharsis bulge region on Mars with Olympus Mons in the top left. Click here for original source URL.

One of the most obvious features on the Martian globe is an enormous trench scarring an entire hemisphere. Valles Marineris, named after the Mariner spacecraft that discovered it, is 4500 km (2800 miles) long - it would stretch across the entire United States! The valley is 8 km deep in some places, five times as deep as Earth's Grand Canyon. Valles Marineris probably has a tectonic origin. Without plate tectonics to relieve the stress, convection in the mantle could stretch the crust, forming a giant crack. Weathering by wind, and perhaps water, would have widened this crack into the chasm we see today. The formation of Valles Marineris may also be related to the Tharsis bulge, a large upwelling in the Martian crust nearby.

Valles Marineris. Click here for original source URL.

Sitting on the Tharsis bulge are several of the solar system's largest volcanoes. These shield volcanoes are relatively young, only about 200 million years old. The largest of them is Olympus Mons, rising 24 kilometers (78,000 feet) above Mars. In comparison, Mount Everest on Earth rises only 9 kilometers above sea level, and 13 kilometers above the deepest ocean floor. Mountains on Earth don't grow as large as on Mars for several reasons. Tectonic plates slide over volcanic "hot spots," so instead of one large volcanic mountain, we get a chain of smaller ones. Secondly, the thicker lithosphere of Mars is also better able to support the mass of a large mountain. Earth's thinner lithosphere and hotter interior causes slumping under the weight of a large mountain.

The only samples we have of Martian rocks are meteorites, and we don't know where on Mars they originated. So scientists have to use craters to estimate the ages of different areas on the surface of Mars. The most obvious age difference is between the northern and southern hemispheres. The northern hemisphere is smoother, with fewer craters, and is also lower in elevation than the southern hemisphere. Perhaps this area was flooded by lava, or it may be the floor of an ancient ocean.

Mars is occasionally covered by planet-wide dust storms that can last for months. Billions of years of erosion by wind, meteorite impacts, and water have reduced surface rocks on Mars to a layer of fine particles. During global storms, the entire planet's surface is veiled by this red dust. The storms are so big, they can even be seen from Earth. Wind speeds at the surface during a dust storm can reach 30 m/sec (67.5 miles/hr)! With this kind of speed, even very fine dust has enough power to sculpt the Martian surface. Changing dune fields and wind streaks are evidence of that influence. Wind will slow down when it passes over a raised feature like a crater or a hill, and then it will deposit material in a streak behind the feature. The streaks can be dark or light, depending on the color of the material and the underlying rock.

Mars before and during a global dust storm. Click here for original source URL.

Every solar system body has craters, but one type of crater is found only on Mars. Rampart craters are surrounded by ejecta that looks like it flowed like mud. When an asteroid hits the surface of Mars, part of its kinetic energy is transformed into heat. This would melt any ice mixed in with the soil, or any permafrost beneath the surface. The resulting water would liquefy the rocks and soil thrown out of the crater, forming the characteristic rampart ejecta blanket. These distinctive craters are one of the indications that ice is present under the Martian surface.

Rampart crater on Mars. Click here for original source URL.

Author: Chris Impey
Editor/Contributor: Ingrid Daubar-Spitale

Figure 3. View of one of the 380 textbook articles in a web browser, with images added from public domain or copyright-free sources. Red words or phrases are in the glossary and hovering over them with a mouse will give a pop-up box with the definition. Clicking on images toggles them to larger sizes for better visibility

major topics, authors and editors have built up the layer of citations, such that an average astronomy article has several dozen of references to the primary literature. We have read over two hundred astronomy articles in Wikipedia among us and find that the quality is high enough to offer our target audience quick information. We "filtered" the entire content of several million Wikipedia articles to identify the roughly 40 000 articles that relate to astronomy and clustered the articles such they can be presented using the Wikimap. On the Wikipedia site, content is not systematically tagged and has consistent no taxonomic organization. Astronomy articles are found by a keyword search and then related topics identified using the hyperlinking within each article. With the Wikimap, closely related articles to the primary search are reliably identified by the clustering algorithm, and a user can "surf" within the entire walled garden of astronomy articles. We use Wikipedia in accordance with the terms of the GNU license.

4.3. Astronomical Images

Since June of 1995, Astronomy Picture of the Day (APOD) has been bringing the public an impressive astronomy image every day with a short, but detailed and scientifically meaningful, description (Fidler 2010). APOD gets nearly 2×10^6 unique visitors each month, so it is one of the most popular astronomy destinations on the Internet (http://apod.nasa.gov/apod/). With the permission of Robert Nemiroff and the administrators at

APOD, we have clustered all APOD images and provide a powerful tool for surfing through this enormous resource of over 6300 astronomy images. We operate as a "new media mirror site," redistributing the content with a different technology, so are within the general boundaries of "fair use" guidelines. The image captions are fed into the clustering algorithm and closely related images are displayed in the Wikimap results. APOD topics change daily so the advantage of this approach is organization added to the resource (Figure 4). Several thousand additional images from the Astropix archive are presented the same way, with the permission of Robert Hurt and the team at Caltech/IPAC (http://astropix.ipac.caltech.edu/). Astropix has images from NASA's space observatories.

4.4. Video Clips

Many formal and informal learners prefer to engage material in short bursts, as they have time and to fit around other tasks. To provide "bite-sized" learning units, we have developed over 1100 1–2 min video clips, more than 25 h of content total, covering all the topics of introductory astronomy. These "talking head" clips were filmed against a green screen, with astronomical image backgrounds added in post-production. This material parallels the articles in providing complete coverage of introductory astronomy, but the "chunking" of the topics is on a finer scale than the textbook articles and is suitable for people who prefer listening to reading. Two layouts are available for video content. Video lectures are comprised of sets of video clips organized analogous to chapters of a book into 29 different playlists. Viewing a playlist is like sitting in on a mini-lecture 20–30 min long; the playlists are built into a *YouTube* channel to allow seamless streaming. The video clips mode of presentation utilizes the Wikimap to display search results in a navigable fashion, starting with a keyword search. Transcripts from the video clips are used for the clustering. *Teach Astronomy* provides the video transcripts on the web site so that any user can have all the topic information readily accessible.

4.5. Astronomy Podcasts

The web site 365 *Days of Astronomy* has been producing daily podcasts since 2009. It was an initiative associated with the International Year of Astronomy but has continued since then, with daily 5–10 min broadcasts made by astronomers from all around the world. With permission from the 365 *Days of Astronomy* creators, we have clustered these podcasts using each podcast transcript as source material (http://365daysofastronomy.org/). The audio plays with a click from the Teach Astronomy web site, and can be

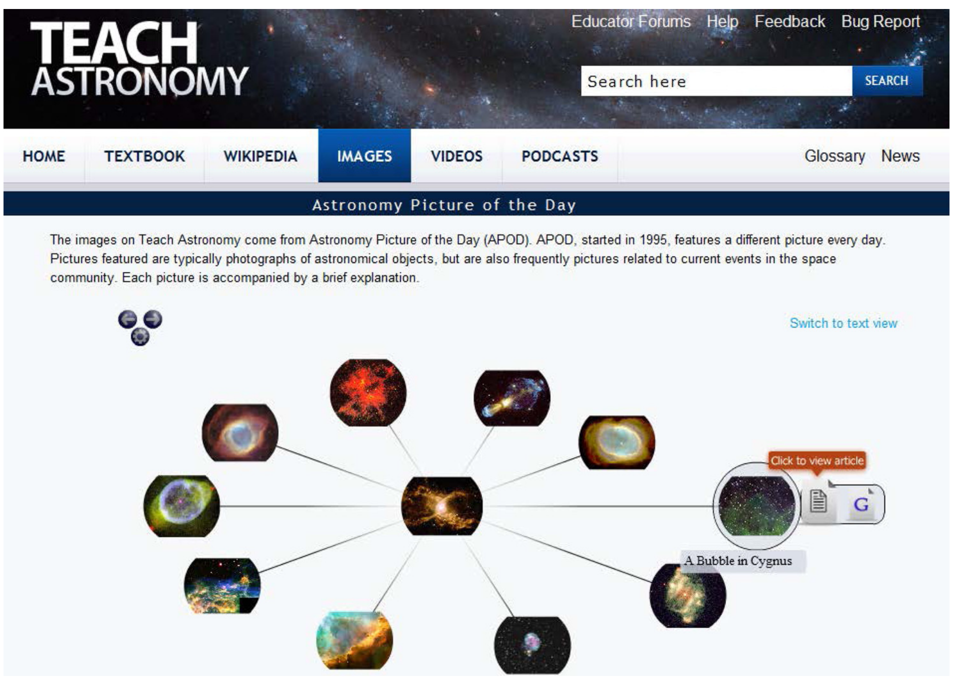


Figure 4. The Wikimap display of images from Astronomy Picture of the Day (APOD), where related content based on an algorithm involving keyword overlap in the captions is the basis for clustering. Clicking on the link to the side of the node goes to the original APOD posting with a larger image, and the second icon launches a Google search based on the image title

filtered with a keyword search. Then, the Wikimap interface allows a user to view the ten most closely related podcasts, and surf to find related content. As with APOD, this mechanism adds value by organizing a resource that was originally produced with topics that vary widely from one day to the next. These podcasts enhance any traditional learning experience with their immediacy and personal flavor: research practitioners describe discoveries in their own words and convey a sense of how science actually works.

4.6. News Stories

The last item of content on the Teach Astronomy web site is an RSS feed of the *Science Daily* resource (2012, http://sciencedaily.com/). *Science Daily* aggregates press releases and news items from universities and research institutions across the country, supplementing them with stories written by *Science Daily* staff. Since the stories are typically written by researchers working with their offices of public information, the quality and accuracy are high and the level is appropriate for a non-technically trained audience. *Science Daily* has delivered over 65 000 science research news articles since 1995, and the RSS feed for astronomy and space science (using only the "Space and Time" category on the *Science Daily* web site) contains 25–30 items per week. These news articles are good starting points for searching and learning about new topics in astronomy and can be the basis for classroom discussion or homework assignments.

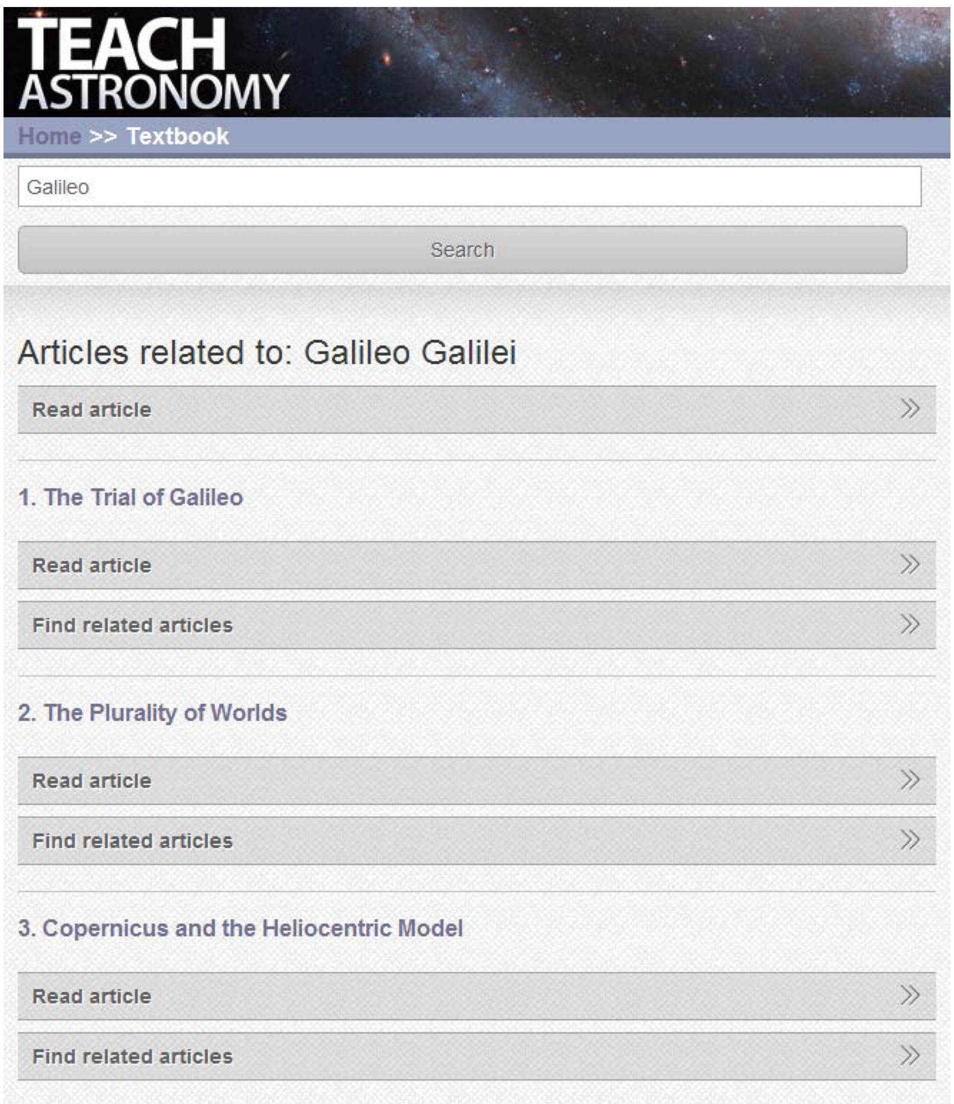


Figure 5. A view of the Teach Astronomy web site on a smartphone, using Galileo as a search term within the content category of textbook articles. The web site senses the handheld device and delivers a list view of items rather than the Wikimap. Users can select and read (or listen to and watch) items and navigate using buttons at the top and a search box

5. USING THE WEB SITE

Teach Astronomy took several years to develop and is now being launched to a wide audience. Navigation is designed to be visually intuitive, but the home page has a link to a help page with a diagram illustrating how to use the Wikimap. There are also links to a page to report bugs and another to give feedback using a short form. We plan to continuously improve the resource and periodically add new features. Astronomy instructors are encouraged to consider using it as a textbook substitute and as an enrichment resource for their classes. Amateur astronomers and informal learners with a general interest in astronomy are encouraged to use it to deepen and broaden their understanding of the subject and to acquaint themselves with the results of recent research. The site formats and delivers content to many handheld devices (Figure 5).

Future development is planned in several directions. Most significantly, we hope to build and support communities of instructors who use the site in conjunction with their classes. Soon we will release a set of sample assignments that use timely information on the site—news stories from *Science Daily*, striking images from APOD, and discoveries described in podcasts from 365 *Days of Astronomy*—in a short answer homework assignment. These templates are designed to progress from specific, factual questions to more open-ended questions that require interpretation or additional investigation to answer. We hope instructors will create and share material of this type, as well as other types of curricula that use the web site. In anticipation of this, we have set up an Educator Forum on the site hosted by Google Groups. Lastly, we plan to augment the site content. In particular, we will be integrating information from the sky map resource WikiSky (http://www.wikisky.org/) and continuing to add astronomical images from space and ground-based observatories. New features will be added every few months as we continue development.

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