Inquiry-Based Learning of Astronomy with WorldWide Telescope

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***Abstract*—WorldWide Telescope (WWT) is a free software program, which brings scientific astronomy data, images, stories and other information together. It functions as a virtual observatory on computer. With many outstanding features, WWT comes to be potentially powerful technological tool that supports inquiry-based learning goals in astronomy education. The practice of WWT based teaching about astronomy has been implemented in an elective course at the Central China Normal University since 2011. Four essential steps in this implementation have been described in detail. Results from the teacher's feedback and the survey which 137 students filled out after the course are presented in this paper. We expect that more teachers and students could benefit from this method when teaching and learning astronomy in the future.**

***Index Terms*—astronomy education, WorldWide Telescope, inquiry, tours, science data**

I. Introduction

With the rapid development of science and technology in this information era, traditional astronomy education has to transform into informational and computational education because the data deluge from multiple sky surveys should be understood by the next generation [1]. Since the National Research Council released the National Science Education Standards for K-12 education in 1996, inquiry-based learning has got much attention all over the world. However, students in China get few opportunities to be enrolled in inquiry-based learning environment before college. It's very necessary to train undergraduates to experience inquiry-based learning especially in science education. The elective course - "Mysteries of the Universe"- in Central China Normal University has integrated traditional curriculum with technology to immerse students in inquiry-based learning environment by using WorldWide Telescope software since 2011. It combines three teaching modes including WWT-based experiment class, theory class and field observation. Students were surveyed by a questionnaire with 20 questions related to WWT teaching, and 137 students offered available responses.

II. Why use WorldWide Telescope?

Alex Szalay from Johns Hopkins University in U.S. has proposed the idea of Virtual Observatory (VO) which refers to the seamless combination of worldwide resources for astronomy research and education between 1998 and 1999 [2]. After two years, Alex and Jim Gray who is a computer scientist in Microsoft Research firstly addressed World-Wide Telescope on Science journal [3] based on VO conception. When the software named "WorldWide Telescope" was released in 2008, it has become a useful tool both in astronomy research and education [4]. Since inquiry-based learning should be integrated into college or university science courses [5] to develop critical thinking skills and scientific problem-solving ability, it is not that simple to just give technology and information to the students, but teachers should make use of technology and give appropriate instructions to engage students in inquiry-based learning. According to the feedback from the teacher and students' comments, WorldWide Telescope has been confirmed that it is the tool with many outstanding features (See Fig. 1) to support the goals of inquiry-based learning in astronomy education.

A. Reasoning with Real Science Data

By providing easier access to the VO, teachers can not only use real science data to teach the scientific process, but also broaden VO's impact beyond the professional astronomer [6].

WorldWide Telescope has collected those scientific data from the best ground and space-based telescopes in the world such as Hubble Space Telescope, Chandra X-ray Observatory, Sloan Digital Sky Survey, etc. Everyone can download this no cost for non-commercial use WWT from its official website and reasoning with all these scientific data. For example, when students explore the black hole, they need to know that black hole is not visible. If binaries in the sky have X-ray emission and one of the compact stars is heavier than a neutron star, it might be a black hole. Therefore, when students switch from Digitized Sky Survey into ROSAT All Sky Survey (X-ray) in WorldWide Telescope to find Cygnus X-1, a strong candidate for black hole, it means they are reasoning with real science data just like astronomers.

B. Visualized Universe in Different Perspectives

Accessing to real science data doesn't mean students need to deal with huge numbers or spectra. WorldWide Telescope has very friendly user interface and visualized seamless all-sky map, which could help students to better understand the universe. When WWT runs on a computer

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or within a web browser, learner can find the label “Look At” at the left bottom of the interface (See Fig. 1). In the drop down list, five modes which are Planet, Earth, Sky, Panorama, and Solar system are displayed. Each mode corresponds to different perspectives and objects. In the Solar system mode, students can explore planets, solar system, and Milky Way galaxy to the real scale. If students need to tell the differences between galaxies, cluster and nebulae, it’s very easy to find high pixel images of these objects in the Sky mode, and summary the patterns by their own eyes. In addition, the survey shows that 83% students (3% standard error) took this visualized sky as one of the advantages in learning astronomy. Thus, this visualized, multiple perspectives, whole wavelengths digital sky could help students understand how universe works easily.

Figure 1. Annotated screen shot of World Wide Telescope interface [4]

C. *Multiple Online Resources Regarding Astronomy*

Information resources are always playing an important role in inquiry-based learning. Most teachers would like to lead students to WWW which is an obvious source of archival and dynamic information that can be used when engaging in inquiry processes such as information gathering, designing investigations or interpretation of findings [7]. However, it would seem valuable to have a system or tool that would help address the concerns science instructors have about information overload on the WWW and the varying quality of online resources [5].

WorldWide Telescope not only offers real science data to users, but also offers a bunch of useful links to Wikipedia, databases and publications regarding astronomy subject. With a right-click on any object in the view of WWT to bring up “Finder Scope” (See Fig. 1), it shows basic parameters of the object such as name, classification, magnitude, distance etc. This is a general knowledge of an unknown astronomical object, but it’s not enough for learners to explore. Then clicking on “Research” button, students can research on their own by looking up SIMBAD, SEDS, NED, SDSS, or ADS. These databases are all used by astronomers very often. In most cases, Wikipedia is a good way to inquiry knowledge in a short time. For those learners who have high prior knowledge on physics and mathematics, they can try to read professional articles from ADS to solve problems or get original data and images from WWT to learn analysis on raw astronomical data. Students who use these science data exploring a virtual but also “real” sky are acting as a scientist who is striving to clarify secrets of the universe. They will become more active and more aspiring than ever [8].

D. *Learning by Yourself and DIY*

Slide-based tour is one of the highlighted features in WorldWide Telescope. It should be the easiest way to integrate the real sky into courseware in astronomy education. From the tab “Guided Tours” at the top main menu, learner could find a large number of tours related to planets, nebula, cosmology, and other interesting topics. These tours which look like small videos telling a story about our universe are mostly made by astronomers and educators. Learners can download and watch these tours in and out of class. This is totally self-learning experience. For those learners in China, Chinese narrated tours are archived in WWT Beijing Community.

WWT also allows learners to edit tours themselves based on their own understanding of the universe. It offers a new method to evaluate achievement of student comparing with conventional evaluation of the curriculum such as examination, paper or presentation. The tour not only shows what students have learnt about astronomy, but also presents their comprehensive abilities including using technology, collecting information, organizing materials, writing script, and aesthetic of multimedia work.

E. Other Advantages of using WWT

Beyond the view of 3D space, WWT allows user to set up observation time and place. Since WorldWide Telescope moves the night sky into a computer, it has brought many advantages to astronomy education such as saving time to do field observations; reducing the consequences of staying up late; stimulating rare astronomical phenomena which users might have never seen; avoiding the influence from bad weather; solving the problem that schools may be lack of real telescopes and so on.

Thus, if VO is a good platform for inquiry-based learning about astronomy [9], there is no doubt that WWT is the best example to verify it.

III. Procedures of Inquiry-Based Learning

Combined traditional curriculums with WorldWide Telescope, inquiry-based learning has been implemented in the elective course named “Mysteries of the Universe”. All students from different departments in Central China Normal University could attend this class. Contents such as constellations, moon phases, galaxies have been taught in this learning style successfully. According to the summary from National Research Council in 2000 that inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. During the real teaching practice, not every step is implemented. Instead, it is rationally designed in accordance with contents and time. Only four essential steps of inquiry-based learning are discussed as follows.

A. Posing Questions

Posing question is a key part in the inquiry-based learning as it determines the teaching content and process of this lecture. Teachers might raise more than one question, but the questions must be extensible and closely related. Students can acquire knowledge and derive joy of scientific research in the process of solving problems.

Most teachers would like to start the course with the history of astronomy. Then the origin of constellation, its function, distribution, and discovery related to sky motion would be introduced. However, it is quite pathetic that students only learnt constellations from astrology which is totally different from what in astronomy science. Hence, the subject "The Special Guardian of Ecliptic" was discussed in class. The teacher proposed questions one after another like “what is ecliptic? Are there only 12 constellations on the ecliptic? What is the sequence of constellations on the ecliptic? Does constellation have something to do with each month?” At last, students can extend the content to 88 constellations of the whole sky under the instruction from the teacher, and learn about the differences between Chinese constellations and modern constellations.

Teachers should be clear that not all the questions need to be investigated by students, so he or she should decide which one or two questions should be offered to do deep research. Given enough time to students, many of them could discover their own questions.

B. Making Hypothesize

Different from other teaching modes, the inquiry-based learning drives students to think hard based on their prior knowledge. After posing questions, the teacher should not provide the correct answer immediately because students will lose the desire to explore and become the slave of remembering knowledge. Therefore, teacher should exam what students have already known, encourage students to make wide supposition, and come up with a preferred answer after thinking over the question. Students can also express their opinions in class freely. Those students with different answers can be involved in a debate to convince others by presenting their prior knowledge on their suppositions. This step is good for the subsequent experiment and analysis.

In the example “The Special Guardian of Ecliptic” before, the teacher gave students 2 minutes to analyze and discuss after posing the question "is there 13th constellation on ecliptic?” Most of students hold the view that there are only 12 constellations on the ecliptic because there are only 12 figures of zodiac they have ever known. Each month corresponds to a constellation, so it is unlikely that there will be the 13th constellation. Minority students believed that there probably exists a 13th constellation on the ecliptic because they guess the teacher must have some reasons of designing the question. The rest of few students might guess that there may be more than 13 constellations on the ecliptic. After students present their suppositions, the teacher offered a brief commentary on these three suppositions, but never gave the right answer immediately.

C. Using Tools to Analyze

In this step, students need to use the powerful tool-WorldWide Telescope-after the teacher has introduced how to use it. When students began to explore the topic in WWT, teacher could observe students' behavior closely which is quite different from each individual. As for the question "Is there 13th constellation on the ecliptic", some students looked at "sky" showing the lines of figures and boundaries and counting the number of constellations along the ecliptic. Some listed the names of 12 constellations they have known and compared them with constellations in WWT. Some directly found out the name of the 13th constellation on the ecliptic from the Internet and dispatched it from the file of "constellation". After all of them figured out the 13th constellation on the ecliptic, they kept on reasoning why it was ignored by people in daily life. The other thing students liked to do was to bring up the finder scope. They would like to find some interesting objects in the sky, and do more research via Wikipedia or SDSS. This is the moment that students construct knowledge by themselves.

D. Communicating the Results

After all students made it clear that Ophiuchus was the special one between Sagittarius and Scorpius, teacher organized students to communicate their findings and further questions. They can talk about how they find the 13th constellation on ecliptic or share interesting information they found from WWT. Teacher compared the final results with the preliminary various hypotheses in front of all students and summarized ideas that why our ancestors made these constellations and how it came to 88 standard constellations. Also, the difference between astronomy and astrology could be introduced in this class.

IV. Findings and Discussion

In the practice of inquiry-based learning with WorldWide Telescope, our results are coming from two aspects. One aspect is from the only one teacher. She was familiar with subject-matter knowledge and pedagogical content knowledge in astronomy education, so it was easy for the teacher to control the inquiry time and observe student's behavior. The teacher thought students enjoyed to be involved in inquiry environment, and they learnt how to solve problems. It was also excited to watch tours made by students because tour with subtitles showed astronomical stories in student's mind. Each tour lasted 1-5 minutes, so it took less time to evaluate these tours than review papers.

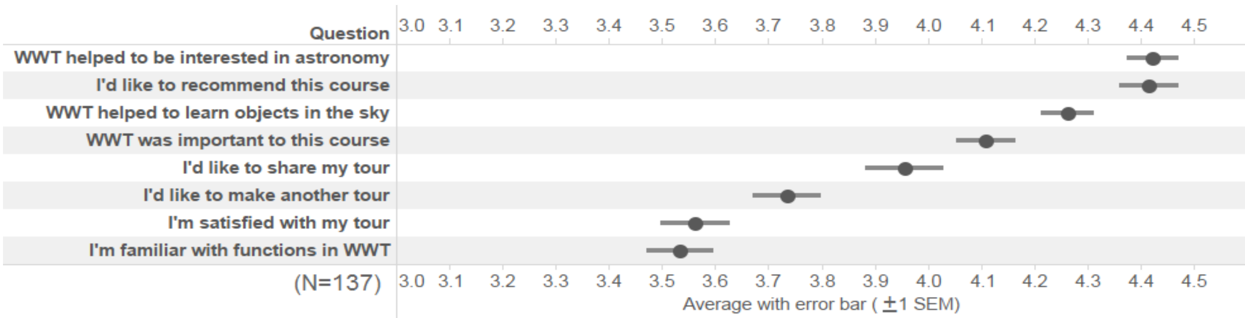

Figure 2. Averages (dot) with error bars (±1 standard error mean) of eight Likert questions. "5" means strongly agreement while "1" means strongly disagreement. The X axis in this plot starts with 3.

The other aspect is from the survey which aims to know students' interest level, satisfaction of curriculum and attitude to make tours. About 137 students offered anonymous responses. From the results of Likert questions (See Fig. 2), we can know that: Firstly, this course wins a very positive comment because majority of students would like to recommend this course others. To some extent, it proves the success of this implementation. Secondly, students speak highly of WWT, even though they are less familiar with functions in WWT. Thirdly, students would like to share their tours with others. As a benefit from it, teachers could use these tours as education resource in the future course and more people will benefit from these tours. Fourthly, students might have a higher expectation on their tours, so they appeared lower satisfaction.

TABLE I. Proportion of Students Who Feel Challenged

Challenges	Proportion	Standard error
Prior knowledge	59.70%	4.24%
Internet speed	55.97%	4.29%
Language	36.57%	4.16%
PC hardware	35.07%	4.12%
Interface	17.52%	3.25%
Others	1.46%	1.03%

We also checked the factors that would impact students when using WWT. At the beginning, the teacher was worried that Chinese students would have difficulty in language because only few menus had been translated into Chinese. However, top two challenges for them were prior knowledge and the speed of internet, see Table I.

The first one is predictable. The second one is because WWT caches pyramidal data via Internet when learner looks at the object at the first time. If learner zooms into a small area to see detailed object, it takes longer time to cache high resolution images to the computer. Thus, it's a suggestion to use high speed Internet and better hardware running WWT if finance allows. This will also reduce the times that computer crashes.

Students also express their ideas on open response question "what do you think about the final evaluation by tour" in the survey. There are 69% students who had no comments on this question. The teacher presumed that they acquiesced in it. 14% students appraised "very good", and 4% students expressed the idea that "it's acceptable but need improvement". On the contrary, 10% students expected multi-ways of evaluation, and 3% students clearly requested other methods like paper or presentation instead of making tour. This tells us most students accept the final evaluation by making WWT tour.

The time student spent in making tour is also investigated by the survey. The results are 7% less than 2 hour, 8% 2-4 hours, 26% 4-6 hours, 40% 6-8 hours and 19% more than 8 hours. This might be one of the reasons that students enjoy making tours.

V. Expectation in the Future

In the future, we would keep on summarizing our experience on using WWT in astronomy education. Meanwhile, different inquiry topics may be developed for both major and non-major students. We expect more and more teachers could make use of this powerful software to inspire student to explore the universe.

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References

[1] K. Borne, S. Jacoby, K. Carney, A. Connolly, T. Eastman, *et al*., “The revolution in astronomy education: Data science for the masses,” *Revolution*, September 2009.

[2] C. Z. Cui, “A Google sky and worldwide telescope era for astronomy,” *Amateur Astronomer*, vol. 7, pp. 63–67, July 2008.

[3] A. Szalay and J. Gray, “The World-Wide Telescope,” *Science*, vol. 293, pp. 2037-2040, September 2001.

[4] A. Goodman, J. Fay, A. Muench, A. Pepe, P. Udomprasert, and C. Wong, “WorldWide Telescope in research and education,” in *Proc. ASP Conference Series*, vol. 461, pp. 267-270, November 2011.

[5] X. Apedoe and T. Reeves, “Inquiry-based learning and digital libraries in undergraduate science education,” *Journal of Science Education and Technology*, vol. 15, no. 5, pp. 321-330, December 2006.

[6] R. William and D. Young. (2009). The role of the virtual observatory in the next decade. [Online]. Available: http://www.us-vo.org/pubs/files/Williams_VO_TEC.pdf

[7] J. S. Krajcik, “The value and challenges of using learning technologies to support students in learning science,” *Research in Science Education*, vol. 32, no. 4, pp. 411-415, December 2002.

[8] C. L. Qiao, X. P. Zheng, C. Z. Cui, and Y. Xu, “Science data based astronomy education,” in *Proc. 2nd International Conference on Education Technology and Computer*, June 2010, vol. 3, pp. 519-521.

[9] G. C. Liu, C. L. Qiao, Y. H. Zhao, and X. P. Zheng, “Virtual observatory and astronomy education,” in *Proc. 6th Cross-Strait Seminar on Extension Education Astronomy*, March 2004, vol. 3, pp. 55-58.

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