“Heavenly Mathematics: Cultural Astronomy” and “Mathematics in Art and Architecture”: Two general education courses at the National University of Singapore

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General Education Modules

For years I was dreaming about teaching a math course that was fun! A course that would give the students knowledge they would treasure for the rest of their lives and that they would pass on to their grandchildren. Knowledge that would make them see the beauty and significance of mathematics, and make them look at the world around them with different eyes. Unfortunately, even the best teachers have a hard time teaching calculus or linear algebra in such a way.

Fortunately for me, in 1999 the National University of Singapore implemented a “General Education” requirement. Faculty members were invited to propose General Education Modules, from which the students were required to choose four. I still remember the excitement I felt when I saw that e-mail! I had for years dreamt about designing multi-disciplinary mathematics courses, and I jumped at this opportunity to fulfill my dream. I’m currently teaching two such courses: “Heavenly Mathematics: Cultural Astronomy” and “Mathematics in Art and Architecture”. In this paper I will briefly describe the content and philosophy of these courses.

Goal of my courses

In both courses I have four goals.

1. Help the students appreciate the world around them and start looking at their surroundings with different eyes. I want them to notice and question things they used to take for granted.
2. Show them connections between mathematics and culture. I want them to stop thinking about knowledge in terms of school subjects, but as part of mankind’s struggle to understand the world.
3. Demonstrate the relevance and importance of mathematics by showing how it solves problem of general interest. I want them to see the beauty and centrality of mathematics.
4. Give the students a chance to excel in project work. 40% of the grade is based on a group project on a topic of their own choice. 20% of the grade is based on group homework like observing the rising position of the Sun and the appearance of the Moon in the course of a month, making models of the Platonic and Archimedean solids and taking pictures of mathematically interesting things around them.

Course content

Heavenly Mathematics: Cultural Astronomy www.math.nus.edu.sg/aslaksen/teaching/heavenly.html starts with basic astronomy, focusing on what the Sun, the Moon and the stars look like from different parts of the world. Many astronomy books take a "high latitude centric" point of view, but I try to be "hemispherically correct" and focus on the tropical point of view. I then look at applications of astronomy with a cultural flavor, like calendars, navigation, archaeoastronomy, sundials and map making. Singapore is a "multi-calendrical" society where we use the Gregorian, Chinese, Islamic and Indian calendars for determining the public holidays. The pattern of sunrise and sunset times in the Tropics is complex, and requires understanding the equation of time. I teach them the basic ideas of celestial navigation, and we have a guest lecture by a submarine officer from the Singapore Navy to talk about modern navigation practices.

Mathematics in Art and Architecture www.math.nus.edu.sg/aslaksen/teaching/maa.html focuses on how we perceive patterns and symmetry. We study tilings, Platonic and Archimedean solids, the golden ratio, rosette patterns, frieze patterns, wallpaper pattern, perspective in paintings and mazes.

Course philosophy

I love mathematics, both for its internal beauty and for its relevance to the world around us. One of the primary goals of my teaching is to communicate this to my students. Unfortunately, many of our students have been deeply traumatized by the way mathematics is taught in schools. In both of my courses, I'm able to show them that mathematics is related to a wide range of everyday phenomena and give them a positive feeling about mathematics.

Until I was 15 years old, I wanted to study history, and I still am a "closet historian". Both my courses are multidisciplinary, and one of my main goals is to make the students see links between mathematics and other fields. I want them to understand that mathematics is not just about formulas, but also about looking at patterns in the world around us. Mathematics is not defined by what we study but by how we study it.

The main reason why I wanted to become a professor is because I love learning! I feel privileged to have made my hobby into my job. One of my main goals is to make them appreciate knowledge and learning and understand that going to a university is not about getting a degree, but about picking up intellectual life skills that will serve them well no matter what they do later in life.

Scientists don't live in a vacuum. It is important to understand the relationship and interplay between science and society. The historical context is an important part of mathematics. I want my students to appreciate how people throughout the world and throughout the ages have struggled with the same problem. It is fascinating to see how they sometimes come up with fundamentally different, but equally valid solutions!

Singapore is not just a multiracial and multicultural society, but also a multicalendrical society! A central part of my astronomy course is a detailed study of the four calendars that determine the public holidays in Singapore: the Chinese, Muslim, Indian and Western calendars. At the beginning of the course, I often get strange looks if I ask Chinese students a question about the Muslim holidays. They seem to think that I'm a stupid foreigner who can't tell that they are Chinese and not Malay. But by the end of the semester they appreciate the links between science and society.

The bookstores are filled with books about astrology, "sacred geometry" and "lost civilisations". I want to give my students the knowledge and thinking skills to enable them to separate fact from fiction.

I do a lot of public lecturing on topics in mathematics, astronomy and art at museums, libraries, science centres and schools. I have also been academic advisor for the exhibition "Art Figures: Mathematics in Art" at the Singapore Art Museum and "The Dating Game - Calendars and Time in Asia" at the Asian Civilisation Museum and for the TV series "Ancient Chinese Inventions" on the Discovery Channel. This ties in very well with my teaching.

When I agree to give a public lecture at a museum, I have no guaranteed audience. I have to come up with an interesting topic and abstract and make sure that working professionals want to take time off their busy schedule to come to my talk. This teaches me not to take my audience for granted. Similarly, when working with the Discovery Channel, I need to be crystal clear about my target audience.

When people come up to me after a talk and say "My mother has always wondered how Qing Ming is determined and now I can explain it to her!" or "Now I can answer the questions my kids ask me about Chinese New Year!", then I know that I have made a difference! When I started planning my courses, I knew they were going to be a success since I had already road-tested them!

Visualization

I believe that there are four levels of knowledge. Knowing, understanding, explaining and explaining simply. Simple explanations often involve visualizations or analogies. For geometrical concepts, I create physical demonstrations involving my own body, teaching props or the students. I have a vast collection of celestial globes, sundials, navigational instruments and soft toys that I constantly use in my classes. On the course web page I say that "I'm not afraid of looking stupid and I hope you're not either". In the student comments, they often say that the demonstrations help them remember the concepts better and that the more hilarious the demonstration, the better they remember it!

For my course on art and architecture, I use various kits for building polyhedra and making tilings. There is really no way you can talk about these topics in a meaningful way without physical models. One of the homework asks them to build paper models of the five Platonic solids. These models are then used for the rest of the course.

IT allows us to go one step further by adding animations and interactive applets. With the help of CITA, I have created Java applets for my astronomy course. They are essential to my course and many web pages link to them.

My lecturing style is very interactive, which makes it hard to make it into a good video. On the other had, I believe in short video clips. Next to the lecture notes and applets on the web page I have created short video clips where I highlight difficult points and give geometric demonstrations. This allows me to take advantage of the strengths of video.

I show several movies and TV programs in my class. Some of them are very good, while some of them are very bad! I use those as starting points for discussions about pseudoscience.

I have an extensive web site. My web page on the Chinese calendar www.chinesecalendar.net is the highest ranked page about the Chinese calendar on Google! Around the time of Chinese New Year, I get up to 50,000 hits each month.

Teaching props and Java applets I use in my courses and public lectures

Figure 1: Building models at an enrichment camp

Figure 2: Comparing the views for a polar bear at the North Pole and a penguin at the South Pole

Figure 3: What does the Penguin have to do with the Singapore flag?

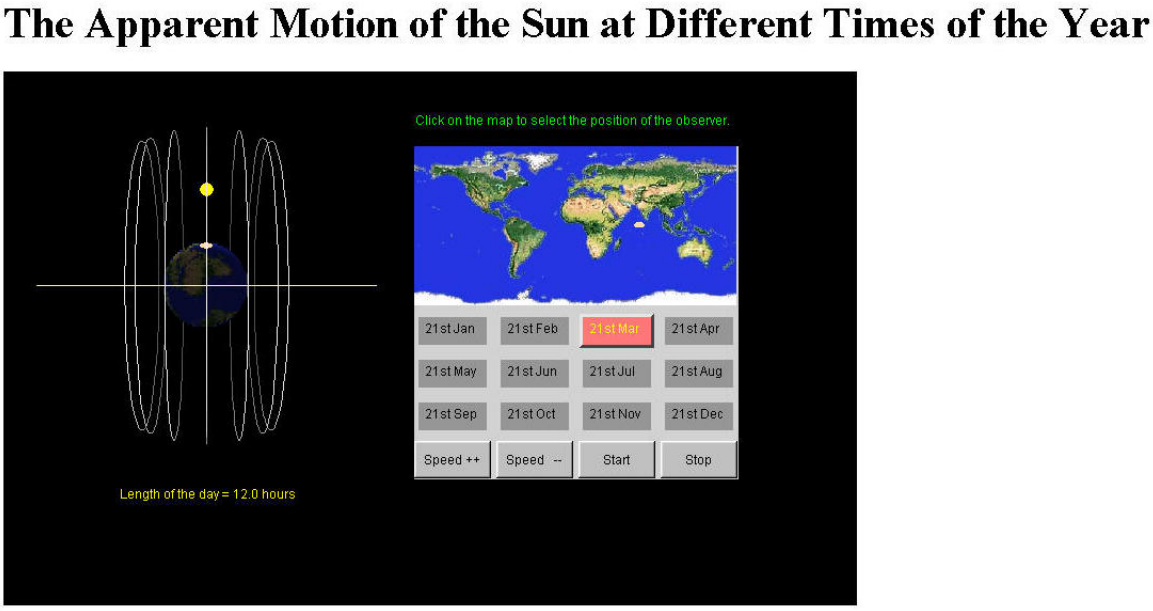

Figure 4: The apparent motion of the Sun at different times of the year as seen by an observer in Singapore.

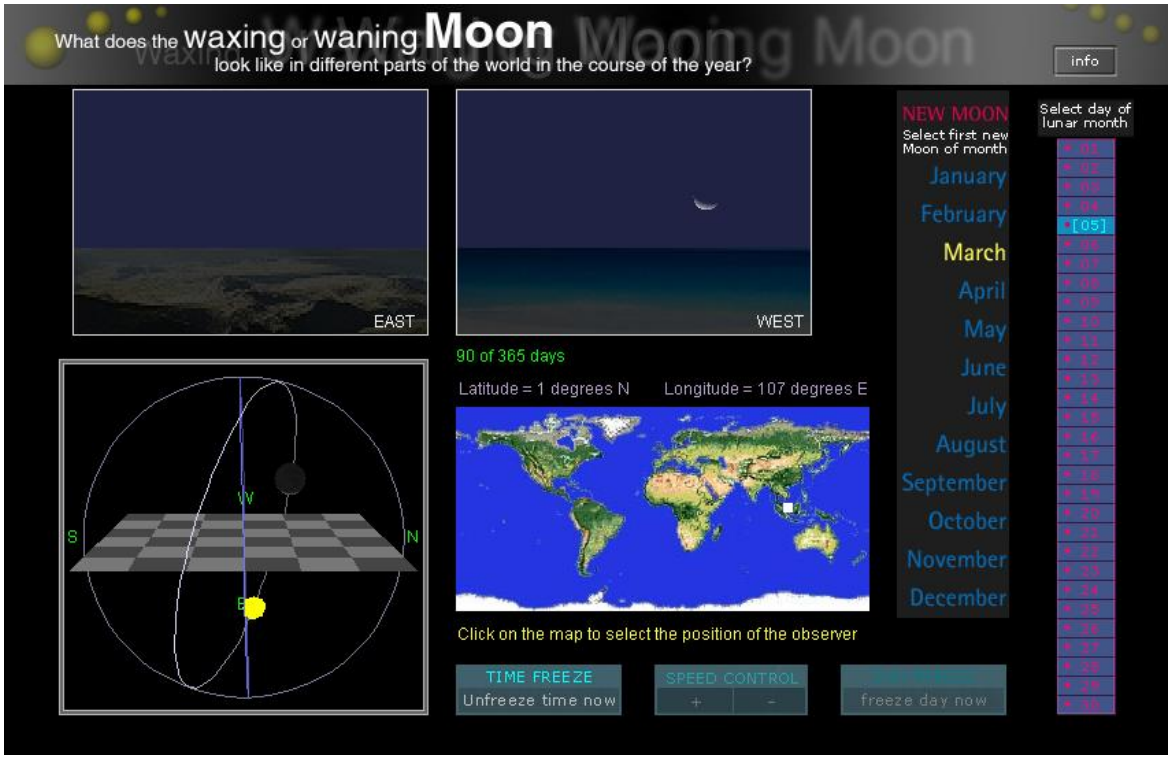

Figure 5: What does the waxing or waning Moon look like in different parts of the world in the course of the year?

Homework and projects from my courses

For both my courses, 40% of the grade is based on a group project. I have a list of possible topics, but I also encourage students to propose their own topics. I tell them that they can write a report, create a web page, make a computer animation, or build a physical model. It is wonderful to see how enthusiastic and creative they can be when they are given the opportunity to do something that excites them.

For both my courses I also assign two innovative homework that count 10% each. For the astronomy course, the first homework is to make two observations of the rising or setting position of the Sun, one in August and one near the autumnal equinox around September 23. The second is to make five observations of the Moon in the course on one lunar month.

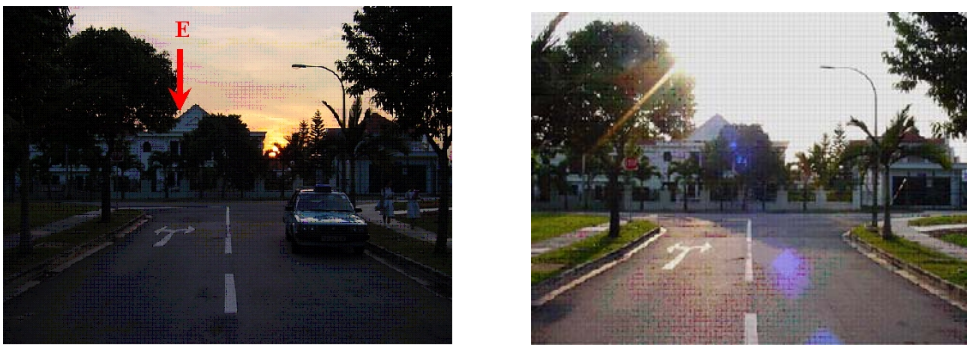

Figure 6: The left pictures shows the sunset in August, the right shows the sunset in September

For the art and architecture course, the first homework is to make models of the five Platonic and 13 Archimedean solids. These models are then used for the rest of the course.

Figure 7: The five Platonic and 13 Archimedean solids

The second homework is to take pictures of five mathematically interesting things around them. Thanks to my students, I am accumulating a huge database of unique pictures from Singapore!

Conclusion

Teaching these two courses has been a wonderful experience for both me and my students. We have all learned a lot, and I hope to eventually turn this material into book form. I would like to thank my students for their enthusiastic response, which was one of the reasons I was awarded the Outstanding Educator Award at the National University of Singapore in 2004.