

Using Calendars to Teach Science

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Abstract

This paper considers the use of calendar construction as an activity for 5th through 8th graders to reinforce science and mathematics concepts. The fundamental cyclic nature of many processes makes it possible to posit alternatives to the modern calendar. Students, in constructing their own calendars, will better appreciate the scientific basis of the modern calendar as well as the cyclic nature of the processes considered in the construction of alternatives. This enhances STEM skills by requiring the students to apply creative mathematical and scientific solutions to a real world problem: tracking cyclic time.

Introduction

Calendars, with rare exceptions, are trackers of natural cyclic processes. Whether lunar, solar or seasonal, calendars track various time periods associated with a variety of phenomena. This paper proposes using the cyclic structure of calendars to reinforce material studied in science classes. Using calendars easily lends itself to individual and group activities that require the students to come up with their own technical solution to constructing a calendar. In doing so students engage in several aspects of STEM education. They consider what they know about cycles in nature, they use basic mathematics and, most significantly, they find a creative solution to a real world problem that has had many different historical solutions. Though the mathematics required for this activity is very basic, students do need some maturity in considering cycles for their own calendars. Therefore, this activity is best suited for 5-8 grade classrooms.

This paper first looks at some historical examples that differ from the modern calendar and reviews the modern calendar structure. An example is then given of a non-traditional calendar along with possible topics and structures that students might consider. A suggested lesson and assessment outline for group activities is also presented.

Historical Examples and the Gregorian Calendar

Most people think of a calendar as a way to arrange meetings, holidays, etc. The modern Gregorian calendar is primarily structured to track the sun in the sky and thereby allow for the determination of the four seasons. Through various historical effects that will be discussed later, the modern calendar has arrived at the familiar 12 month/52 week/7 day structure. Students having only experienced this one calendar are rarely aware of the many historical variations.

The Egyptian calendar for example had a fixed 365 days (no leap day) and was divided into three sections: Inundation, Growth, and Harvest. So tied was Egyptian society to the flooding of the Nile that there was no significant recognition of our traditional seasons. The year started based on the particular rising of the star Sirius. Though the onset of the Nile floods is connected to seasonal effects and seasons are determined by the Earth's orbit, the Egyptian calendar cannot be said to be solar, since the sun's position was not tracked.

Likewise, the ancient Chinese Five Phase calendar has an unusual structure. This calendar divides the year into five phases of 73 days, each associated with a different festival. Each phase is divided into two 36 day “months”. The additional day in each phase is the festival day. This calendar, like many others, has a fixed 365 days. This is a solar calendar and uses the sun’s position to determine the start of the year. Though the 36 day sections are much like our months, we have nothing in our calendar that corresponds to the five phases.

There are many historical variations that students can research online. This could easily be part of a classroom activity where students present extinct calendars and contrast them to the Gregorian calendar. Duncan (1999), Richards (2000) and Stern (2012) give more thorough backgrounds on the history of calendars.

The modern Gregorian calendar is the first case of a calendar gaining world-wide acceptance. It also represents the most accurate solar calendar. Here, for the sake of space, is given a short discussion of what distinguishes the Gregorian calendar. There are many well written, detailed discussions of the history and structure of our calendar. Boorstin (1985) and Shimony (1997) in particular give excellent presentations. Table 1 summarizes the three calendars just discussed.

Table 1. Shown are summaries of the three calendars noted in the text.

Calendar	Number of Days in Year	Natural Basis	Description
Egyptian	365	Nile Flood	The year is based on the rising of Sirius and divided into the three seasons of Inundation, Growth and Harvest.
Early Chinese	365	Sun	The year is divided into five 73-day phases, and each phase is divided into a festival day and two 36-day months.
Modern (Gregorian)	365 or 366	Sun	Introduced in the 16 th century as a correction to the Julian calendar. It is now the standard worldwide calendar.

The problem with many past calendars was that they had a fixed 365 days in a year. This would be fine except it takes the Earth just under 365.25 days to orbit the Sun. So, since our solar calendar is tracking the sun to track the seasons, it is off by about one-fourth a day each year. This may not seem like much and it doesn't make a difference for farmers over just a few years. But, over a century the calendar would be off by almost 25 days. This would, and did result, in farmers confusing brief warming trends with the actual onset of spring. To address this the leap day was introduced and used in several calendars, Boorstin (1985). However, adding the additional day once every four years is actually an over correction since the year is a bit under 365.25 days. The Gregorian calendar fixes this by not always having a leap day every four years. The calculation works like this; If the number of the year is divisible by 4 a leap day is added, unless the year is divisible by 100, then the leap day is not used, and unless the year is divisible by 400, then it is added back in. So, 2016 is divisible by 4 so is a leap year. The year 1900 is divisible by 4 so a leap day is added, but it is also divisible by 100, so the leap day is taken out; thus 1900 was not a leap year. The year 2000 is divisible by 4 so the leap day is added, BUT it is divisible by 100 so the leap is taken out, BUT it is divisible by 400 so the leap day is added back; thus 2000 was a leap year. (A trivial task for older students, younger students get an arithmetic exercise

out of this.) This modification of the leap day made the calendar accurate to within a day for several millennia. More can be found in Coyne (1993) and Moyer (1982).

Though the Gregorian calendar modified the calculation of the leap year, it kept commonly used names for the days of the months and weeks. The "month" is historically associated with the moon. Most years have 12 full moons and the "month" is a vestige of tracking the lunar phases. The week actually has no astronomical correlation and the use of the week, though common in many calendars, varied in length from 5 to 10 days. Students may find interesting the origin of the names of the months and days of the week. The months' names have a Roman Empire origin, while the days of the week are a combination of several sources. Sunday, Monday, and Saturday's origins can still be seen in their spellings; Sun, Moon and Saturn. The other days of the week have their origins in Norse and Germanic gods as summarized in Table 2. Details of these designations can be found in Blackburn (1999), Brown (1989), Falk (1999) and Richards (2000).

Table 2. Given are the days of the week for the Gregorian Calendar and their origins.

Day of Week	Root of Day's Name
Sunday	Sun's Day.
Monday	Moon's Day.
Tuesday	Tiw's Day. Tiw was a one handed Norse god associated with solo combat.
Wednesday	Woden's Day. Woden was a German god who guided people after death.
Thursday	Thor's Day. Thor was the Norse god.
Friday	Frige's Day. Frige was the Norse name for the planet Venus.
Saturday	Saturn's Day. Saturn was the Roman god who fathered Zeus and many of the titans.

Alternative Calendars

As successful and widely accepted as the Gregorian calendar is, there is no physical requirement that it be used. We could propose a new calendar. Students can propose their own calendars as possible alternatives. Here is presented a simple alternative and suggestions for class discussion. Then a list of alternative bases for calendars is given.

An alternative calendar that has a far simpler structure from the Gregorian would be to have 12 months of 30 days each, then have the year end with 5 or 6 days of a "Winter Festival". Furthermore, this calendar would have each month appear the same by having 6 day weeks. So each month would be 5 weeks of 6 days each. (I would strongly argue for keeping a 2 day weekend.) This could be appealing because of the celebration of the fairly common winter holidays. It also would have each month look exactly the same so a particular day of the month would always be on the same day of the week. Suggesting this to students gives them a chance to name the months and weeks, but also gives them the chance to see the strengths and, more importantly, the weaknesses of the calendar. Brainstorming will lead students to realize that their birthday (and all holidays) will always be the same day of the week. Further, they'll need to structure the winter festival days "outside" of the regular calendar and give them different day names. And, hopefully, they will see a strong cultural bias in the recognition of the winter festival depending on their

country's prevailing cultures. Regardless of the level and content of discussion, it certainly gives a chance for students to participate.

Better than students just commenting on a proposed calendar is to construct their own alternative. The key thing for a calendar the students can reasonably construct and discuss is to identify an annual cyclic phenomenon. Though they could abandon the yearly cycle and propose a calendar with a different period, this might be a bit too complicated. All of us are tied to the Gregorian calendar in planning our lives and so, coming up with alternatives may be difficult. Though it's preferred for students to come up with their own alternatives, given below is a list of suggestions to help seed student thinking.

Lunar Phases: Not mentioned in this article are the various calendars based on lunar phases.

More Seasons: A calendar to introduce seasons to replace months.

Migration Patterns: Much like the Nile flooding, a calendar could be based on animal migrations

The School Year: A calendar could be divided up to match an academic year. There could even be different structures for the semester and summer divisions.

Temperature: Looking at the average high (or low) temperatures students can see patterns that would lead to various divisions.

Sports Seasons: Couldn't the year be divided into seasons not based on climate but rather on what sports were being played?

Fictitious World: Calendars could be constructed for "worlds" the students know through fiction or that they create themselves.

Regardless of what the students choose for their calendar basis, they face similar challenges that point back to the remarkable success of the Gregorian calendar. Looking back at the examples of the Egyptian and Chinese calendars we see these issues. When the Nile floods would have no significance to farmers in Australia. Likewise, a calendar based on the 5 Chinese festivals isn't going to be popular among most Londoners.

In the Classroom

To incorporate this calendar project into the classroom, teachers have a wide variety of possible approaches. On the following page is a suggested plan of presentation and assessment that is assuming the students will work in groups and that minimal resources are available. The objective of this lesson is that students learn about the basic structures of our calendar by direct instruction and through the construction of their own calendars.

Sample Lesson

Materials: Rulers/meter sticks, pens/pencils, large unlined paper to make calendars on.

Lesson Outline:

- Discuss the Gregorian (modern) calendar's structure.
 - Number of days, weeks and months
 - Why they have their names
 - Leap day calculation
- Cycles that the calendar is based on
 - Motion of sun in sky for the year
 - Phases of moon being close to a month
- Presentation of historical alternatives
 - The Egyptian calendar and lunar calendar are good examples
- Class as a whole suggests other possible cycles to use.
- Students break up into small groups and design their own calendars.
 - Groups should pick a cycle they wish to use.
 - Then pick divisions they want. (analogies to week/month/year)
 - They should identify names for their divisions.
 - Construct the "rules" for making their calendar.
 - Make a sample "month" (or a full cycle) on the blank paper.
 - Students identify a list of strengths and weaknesses of their calendar including any objections people might have.

Assessment: Whether as group work or individual projects, students would benefit from having classroom presentations of their calendars. Primarily this lets the other students in the class think about cycles they may not have considered as well as objections to their calendar.

Grading of the presentations should consider:

- Is the calendar based on real world cycles?
- Do the numbers of the cycles add correctly?
 - (Incorrect to have 50, 6 day weeks in a year and
 - Have 350 days in year.)
- Do the designated names creatively match the cycles chosen?
- Are the students able to anticipate objections?

Additional Activities

The above lesson plan can help students appreciate the complexity of our modern calendar and the challenges of creating a calendar. Certainly an important part of STEM education is the appreciation of the connections between everyday life, culture and science. To emphasize this, students could do one of the following activities:

1. Students who know a bit about their family's past could write a report on the obsolete calendars used in their ancestor's region. Important to this is that the students learn about how and why the calendars are different. The way people lived and what they believed shaped, and were shaped by, the calendars used.
2. The modern calendar is, of course, how we track the days of the year. It is in fact part of a very sophisticated tracking of the time. Precise timing and synchronization of clocks is critical to the functioning of many modern devices. In fact, modern time keeping just does not have a leap day, but also a leap second. [See McCarthy (2008)]. Online, students can learn much about the leap second and the precise work of the U.S. Naval Observatory.
3. With the recent explosion in exoplanet discovery students could consider what a calendar might look like for an alien planet. In particular, the recent discovery of a relatively nearby star that has several rocky planets around it could lead to students suggesting some very unearthy calendars (See Gillon [2017]). Though far from applied science, this activity would certainly spark interest and classroom discussions.

Summary

Through the study of previous and modern calendars and by constructing their own calendars, students can engage in STEM through science, basic mathematics and creative problem solving. The construction of calendars can easily be tied to the study of planetary motion and the changing of the seasons. More generally it can be connected to any cyclic process. The fact that most calendars have been tied to natural cycles should not limit the students from considering other phenomena.

Calendar construction lends itself to individual and group work across a broad range of abilities. Furthermore, the cultural use of calendars gives the chance to not just teach about cyclic processes, but to better appreciate how the significance of events varies culturally.



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