Old and Current Techniques in Secondary School Teaching: The Eratosthenes’s Measure

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Abstract
The technological solutions continuously proposed by the market, also for the teaching applications, are more and more sophisticated. The result is that more time is actually spent on learning the tools than in exploiting the didactic content that may be contained in the programs themselves.

What we have tried to do is to get students to use the most economic, easy, essential, and where possible, state-of-the-art technologies. We have designed and realised a project which consists in reproducing the experience of Eratosthenes, who measured the terrestrial meridian more than 2200 years ago and whose results only differ by 0.8% from current findings.

This work shows how, using a suitable mix of old and current technologies, it is possible to obtain formative results with a current value.

Keywords
Education, Educational tools, Teaching, Secondary school

Introduction
Increasingly sophisticated solutions are often proposed for in-school use. In order to utilize these instruments, the constant upgrading of the equipment (HW) and the application packages (SW) is necessary. For a correct and productive utilization of such instruments, it is therefore necessary to prepare and update teachers and students in an adequate manner.

We often have the sensation of being involved in the pursuit of a technology in evolution with rates, which have nothing in common with scholastic rates, or teaching in general. In many cases we note a certain pervasiveness or at times “aggressiveness” in the displays and commercial expressions proposing the use, or better, the “consumption” of said technologies.

There is consequently the risk that the efforts, the resources and the various teaching disciplines become to a certain extent absorbed in the acquisition of mediatic and instrumental type competencies, leaving less space to the analysis of the contents and to the instructive activities pertaining to the actual disciplines (McLuhan, 1967).

The line we have followed has not been that of renouncing or being opposed to the introduction and the use of new technologies. In relation to what is set out above and in relation to the effective situations in a majority of the schools, we have attempted to verify which teaching and formative interests can be mobilized with a more easy, essential and “current” type of technology.

We used “old techniques” to solve the problem chosen as a case to study and “current techniques” (ordinary tools) to overcome other problems as for example to simplify and increase the speed of calculations or make possible an actual and effective collaboration involving classrooms located at long distance between them.
We focused our attention on "the shadow". The reasons of this choice are that the shadow is an everyday tool, it can be used for example to protect us against the sunray when it is too hot; is a very manageable tool (see the "shadow play"); is largely used in the arts; is largely used for astronomical purposes; it was used in geometry. More precisely, the experiment we have realized (Tropiano, G. et Al., 2000) is that of allowing the students of three different high schools, "Bredtvet" in Oslo (N), "Cassin" in Bayonne (F) and "Salutati" in Montecatini Terme (I), to realize the Eratosthenes's experience, with a few important differences.

The present paper is an extended and modified version of the paper presented at the First International Workshop "Developing Creativity and Large Mental Outlook in the Computer Age" (Tropiano, G. et al., 2000).

The experiment

In the third century b.c. Eratosthenes measured the terrestrial meridian achieving an extraordinary result: the value obtained is in accordance with the present value within a 0.8% range.

The experiment was depicted by Cleomedes about four centuries later. This is the only description available today of Eratosthenes's experiment, since the two books written by Eratosthenes on the matter were lost.

The experiment is based on the measuring of the angle between the ray of sunlight and the ground perpendicular. This angle is measured in two different places positioned on the same meridian at a given distance. Eratosthenes used Syene and Alexandria. The measures are taken the moment in which in both places the sun and the center of the earth lie on the same plane. Under these conditions, the problem is reduced to a plane geometry problem and it is easy to see that the difference between the angles measured is equivalent to the angle of the center of the earth between the two places chosen. Consequently, knowing the distance between same, it is possible to obtain the length of the circumference.

Our measurements are of two different types: one is taken along the meridian and the other along the parallel.

Along the meridian

Montecatini and Oslo are situated on the same meridian. With the students from Bredtvet high school we reproduced the measurements taken by Eratosthenes during the summer solstice. The measurements were repeated for a few days in order to have a certain amount of data and to have good weather conditions in both places simultaneously.

Along the parallel

Montecatini and Bayonne are situated on the same parallel. The measurements were based on the determination of the ΔT time interval between the point in which the sun finds itself at the culminating point (maximum height over the horizon) in both places. The synchronization took place on the basis of the time supplied by the [http://tycho.usno.navy.mil/what.html](http://tycho.usno.navy.mil/what.html) site. Through a simple ratio one obtains the length of the parallel: \( C_p = \Delta S \times 24 \times 60 / \Delta T \). The maximum circle has a value of \( C_m = C_p / \cos \phi \).

\( \Delta S \) is the Bayonne–Montecatini distance, 24*60 are the minutes contained in 24 hours, \( \phi \) is the latitude.

The Oslo–Montecatini and Bayonne–Montecatini distances were obtained from maps on a 1:1,000,000 scale.

The two experiments supply the same results within a 2% range even though the two methods differ substantially.

The geodetic point

A teaching experiment related to these measurements was the determination of the geodetic point in the vicinity of the “Salutati” (Montecatini Terme (I)) high school. Said determination was rendered possible by the kind collaboration of the Military Geographic Institute of Florence. The Institute’s technicians determined the point in
a courtyard inside the high school with a millimetric accuracy. Such accuracy is greater than what is effectively necessary for our measurements but was achieved in the best conditions for teaching purposes.

**Utilization of “old” techniques**

An essential instrument for the measurements taken is the “gnomon” for the determination of the length of the shadow. It is an instrument utilized for many purposes (determination of the time, direction, height measurements) since more than two thousand years. The gnomon may be obtained by driving a stake into the ground (perpendicularly). At a first glance, the measure of the shadow’s length seems to be very simple: we could think to have a good measure (reducing the relative error) taking a big gnomon or stick, or for example, a tower and looking the shadow cast by the top edge of the tower.

But in a real situation we will discover that the sharpness of the shadow (that leads the error on the measure) is mainly due to:
- the angular amplitude of the source (the sun looks like a disk with an angular aperture of ½ degree at noon);
- the light scattered by the atmosphere (which depends at its turn on the clouds presence, humidity, pollution of the atmosphere, and so on).

The problem arises from the real situation, and its solution required a long and complex discussion. This discussion was made via e-mail and along several days with the contribution of students and teachers of the three classrooms involved. This kind of discussions requires an intense exchange of texts and figures between the subjects.

The solution found was using a tube with diameter and length chosen to match the angular amplitude of the sun and using a screen to reduce the scattered light from the atmosphere. With this simple device, it was possible to have an error on the single measure of about 1%.

**Utilization of “current” techniques**

During the planning process and, as seen before, during the search for solutions of the problem chosen, a big amount of data exchange (texts and diagrams) was required between the three schools involved in this work.

The use of the electronic mail system allowed a direct participation of the students from three classrooms located at so distant places and also allowed a big amount of data exchange.

To obtain a temporal synchronization with an error margin below a minute over a period of a few months, we utilized the site of the US navy mentioned above, which supplies the GMT.

**Objectives**

Specific objectives of this experience are the following:
- to realize an experiment in real conditions;
- to handle current technologies with a definite purpose;
- to handle and try to reduce the measure uncertainty;
- to cooperate with other students to solve a problem.

The described experience constitutes part of a teaching modulus centered on the Hellenism, this important historical period greatly influenced the formation of western culture. As a result of the scarce amount of time dedicated by high school scholastic programs to the study of a period covering a few centuries, the knowledge acquired in school regarding that cultural experience which, under many aspects, is exceptional, is in an optimistic hypothesis fragmentary and superficial (Russo, 1997).

Amongst the objectives common to the various disciplines involved (physics, history, mathematics, data processing, geography, history of religion), one will find the following:
- to catch the analogies between the manifestations of civilizations also far away in time (Hellenistic cosmopolitism – European cultural unity);
- to overcome the scientific knowledge-humanistic knowledge dichotomy;
to have a vision of the development of technology over a period of two millenniums from the Hellenistic period to the present civilization (from the gnomon to the GPS).

to have a perception of the diversity of the components of the European civilization through the communication difficulties between the different languages and, at the same time, be aware of the cultural unity through the efforts to achieve a common objective.

Conclusions

In this work old techniques furnished a case to study that presents problems (i.e. learning opportunities) due to the reality of the situation and that stimulated the search for solutions. Current techniques are being used to allow a collaboration between schools located at long distance and to solve other problems too as in this case the problem of the time synchronization. A suitable mix of old and current technologies can produce formative results with a current value.

The presented experience requires the use of the Internet, and it needs a few conditions to be utilisable in any part of the world. It can be repeated between two schools located along a meridian, or in alternative, between two schools along a parallel.

As a future development one can think to realize a numeric simulation that could allow the measure of the circumference of the earth using any two places with the only condition that they must be illuminated by the sun at the same time.

References

