Description Case study: "The contribution of Nicholas Copernicus observations to the reform of calendar"

-for exchange within the HIPST project

1. Title

"The contribution of Nicholas Copernicus observations to the reform of calendar"

Key words**:** *calendar, the apparent motion of the Sun, the experiment of Copernicus, reflex gnomon*

2. Authors and Institutions

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3. Summary

In the lower secondary school teachers introduce students to the world of knowledge ... to implement their independence ... Education should mostly focus on: ... "To develop social skills through the acquisition of valid student's experience in intercourse and in a peer group."

According to the above general objectives of teaching on the third stage of education as the Case study, we propose to carry out research ***interesting physical experiment*** *for those* ***young People who want*** *to spend some time exploring the course of describing the fundamental physics and astronomy in nature (educational objectives in teaching of physics), and stimulate interest in the broadly defined geographic area (educational objectives in teaching geography).*

The task of the school is "to show the importance of discoveries in science for the development of civilization," ... and this can be achieved through inter-subject correlation. And all of this to the young man finishing lower secondary school could apply by geographical knowledge in life, skilfully observed and described the physical and astronomical phenomena, skilfully used the conventional inquiry methods for physics and astronomy, and operated on the basic historical categories: time ..., and variability.

Taking into account the complex development of the various issues we propose both: to equip Students with information about the physical - astronomical – geographical and historical nature as well as with the skills needed to function in society and in everyday life. Interesting experiment that combines so many elements is the experiment of Nicolaus Copernicus, who had an impact on the reform of the calendar in the sixteenth century. During repetition of observations of the famous, born in Toruń astronomer, young people learn about the gnomonic-reflection method and independently carry out lasting more than two months experiment. As a result of the observation they plot the conical curves, which are alike to the results of Nicolaus Copernicus, providing a finding of Spring equinox.

The issue raised by the above Case study is contained in the following themes of Polish core curriculum:

- *History: Europe and the Mediterranean world in the Middle Ages ...*
- *Geography: Earth as part of the Universe.*
- *Physics: Solar System ... propagation of light - phenomena of reflection and refraction of light, Nature of light.*
- *Philosophical path: The most outstanding representatives of ancient philosophy: ... Aristotle.*
- *Regional trail: Elements of the history of the Region and its most prominent representatives.*

Interesting, not typical physical - geographic ***experiment was conducted at the school*** *for more*

than a dozen students, as creation of opportunity for physical experience and to familiarize them with the methods of observation, research and description of the physical and astronomical phenomena, as this is a task of this institution.

At the physics lesson, after presenting the results, students lively discussed and planned to repeat the experiment willing to correct the imperfections made during the first observations.

4. Description of Case study

Physical and astronomical phenomena that are the subject of Case study are usually presented in school in isolation from history. With an "astronomical table" of Nicolaus Copernicus a common problem for physics, astronomy, geography, philosophy and history may be combined.

The purpose of Case study is to present the scientific gnomonic – reflection method, used in the castle in Olsztyn by Nicolaus Copernicus and to check whether this method can determine the solar equinox days at the present time. Due to the time duration of experiment, the following process during Case study has been planned: introductory lesson, execution of the experiment and the main lesson. During the introductory lesson, students learn about the reflective gnomon method used by Nicolaus Copernicus ***(scenario of introductory lesson),*** *and present themselves willing to work.*

Before proceeding to reproduce the experiment it is necessary to choose a place to carry out observations (in our case it was a school room), so that the windows of the rooms facing the south (northern hemisphere). You should also prepare the necessary apparatus for the experiment - the mirror on the stand, e.g. due to the activity of one of students).

Volunteers were divided into three teams and have agreed on principles for the conduct of the experiment:

- *we carried out experiment once a week (Wednesday)*
- *if in the particular day of the week the weather was not good enough we conducted observations in the first nearest sunny day (except Saturday and Sunday).*

Measurements were made a three times a day:

- *first on 8.30,*
- *second on 12.00,*
- *third at 15.00, local time.*

Then, for two months, students were marking observation points on the ceiling. After marking of the last two points, together with students and in collaboration with the Institute of Physics, NCU involved People, we "moved" the selected points on the coordinate system.

After finished observations, during the main lesson of physics, all students familiarized themselves with the results of an experiment conducted with a group of eager young People – their colleagues. Students in the classroom with the use of special experiments were acquainted with the purpose of Copernicus and volunteers observations and with the results of these observations ***(scenario of the main lesson).*** *During this lesson young People strengthened the concepts of rotational and progressive (at the orbit) motion of the Earth and found out why and what kind of conical curves appear either on the ceiling or on wall. In addition, in the next step the picture of astronomical table made by Nicolaus Copernicus in Olsztyn in 1517 (*the authenticity *of this table was confirmed in 2009) have been presented to students during the multimedia presentation.*

In our case, introductory lesson was carried out in the last week before the winter recess for students in grades second and third. The first points were marked on 18th February and the last 22 April 2009. Main lesson was conducted as the last lesson in the school year 2008/2009.

By performing the described Case study we can ask: "Are our students the first in Poland and perhaps in the world, in my care, who recreated the famous experiment of Nicolaus Copernicus?"

5. Historical and philosophical basis, including the Nature of Science (NoS)

Nicolaus Copernicus, who was born in Torun in 1473, is most known for his work published in the year of his death (1543 year) "On the Revolutions of Heavenly Spheres ..." ("De revolutionibus") containing a lecture about the heliocentric solar system of our Universe. In his time the geocentric model obeyed (in the middle of such system is the Earth and other planets - moon and sun on the third orbit in the circular motion) is described by Ptolemy in the second century. Polish astronomer argues that in the middle of the heliocentric system is the Sun and other planets, moon, and earth on the third orbit, are in the circular motion.
It turns out that Copernicus left behind also another souvenir. It is survived to our times the original astronomical instrument at the castle in Olsztyn, used to determine the day of Spring equinox, with the apparent movement of the sun observation - ***astronomical table****. It was helpful in measuring the time a complete revolution of Earth around the Sun.*
Based on archaeological research we know, that this tool set days of the Spring Equinox in 1517 on March 11 Julian calendar.

It is believed that the astronomical table is linked to the work of Copernicus on the reform of the Julian calendar, which was invited in 1513 by Pope Leo X via Bishop Paul of Middelburg.
During the time of the famous astronomer, the Julian calendar obeyed, which had an average year 365.25 days. At the Council of Nicaea in 325 year when it was decided when should be so called "movable feast". Particularly it was concerned with Easter, which are set to begin on the first Sunday after the first spring full moon, so after the spring equinox. Initially, the spring equinox were on March 21, but over the years this date began to shift. In the thirteenth century, scholars talked about the need for change, but to the time of Copernicus could not enter them. Only in 1582, Pope Gregory XIII reformed the calendar, which runs today and is called the Gregorian.

The case presents a study proposal of repetition of Nicolaus Copernicus observations, who has used his research as a first principle of reflection, which consisted in selections of successive points on the sun's rays reflected off the mirror. During the experiment, young People carry out their own experiment through the selection of points at a specified time and in accordance with their own "inventions" and jointly developed methods. Through such work they will know the difficulties of observing the sky and often also their helplessness.
The project has physics and astronomy components, but also the history (calendar) and philosophy elements (geocentric and heliocentric system) to present a broad aspect of the work and thought of such phenomenal man as Nicolaus Copernicus was.

6. Target groups, the importance for curriculum and educational benefits

This case is a research proposal for young People studying in secondary school (13 - 15 years). Activities are conducted at school. There may be the optics lessons - especially when discussing the properties of light or law of light reflection. We present the observation by way of Nicolaus Copernicus (scenario of introductory lesson). May also be extra-curricular activities, or take the form of a research project.

Concepts and physical phenomena, which are used during the activities include: rectilinear propagation of light and the law of light reflection, mirror, gnomon, reflexive gnomon , geocentric and heliocentric system, ecliptic, celestial equator, the equinox, calendar, "white nights", rotation of the Earth, progressive motion (circulation) of the Earth, the apparent motion of the Sun .
There also well-known figures in the history of philosophy appear: Aristotle, Ptolemy, Aristarchus and Copernicus.

Some of these concepts are already known to pupils from first class of gymnasium. Within the content of teaching geography of the Earth as part of the Universe a young student learns issues of the ecliptic, the celestial equator, Earth's rotation, progressive motion *(circulation) of the Earth and the apparent motion of the Sun. While within the content of physics education with elements of astronomy - the youth meets the construction of the Solar System and take the description of the history of the Universe: geocentric system of Ptolemy and Copernicus heliocentric theory.*

During the course of this Case study depending on the suggestions of an appropriate curriculum, students learn or consolidate the above mentioned optics concepts.`

At the end of the project students understand the basic properties of light, in particular, rectilinear propagation of light, the law of light reflection and the apparent motion of the Sun. In addition, learn about the development of knowledge and physical and technical skills related to gnomon.

Within two months of work, they acquire the ability to communicate and collaborate with each other and adults (including parents, teachers, staff and Management Committee of School as well as the staff of the Institute of Physics, NCU). It is very important that students learn at the same time responsibility for an experiment carried out. It would be enough that one team did not make measurement and the work of other groups would be pointless. Of course, sometimes it was so, that the measurement was impossible to implement due to the bad weather, for example in the morning, but already at noon and afternoon we could determine the points. However, we knew that thanks to modern methods of mathematics and informatics we are able to find a missing point.

Because the teams were triple, the students watched each other and to the extent of their capabilities and skills they approached responsibly to carry out the experiment. It is also important that in this experiment all the students may attend, and therefore these very capable and less capable, but also sometimes the students, who create educative problems.

7. Activities, methods and tools of learning

Ongoing Case study shall be undertaken the following actions:
1) The introductory lesson - students learn the scientific gnomonic - reflection method used by Copernicus, and achieved the planned operational objectives through the experience of using a laser pointer, a mirror and a piece of paper. At the end of the session motivation discussion was initiated aimed at invitation of students to carry out the Copernicus experiment.

Fig. 1. Picture of ceiling, where the measurement poits were marked

2) During the more than two-month observations students marked at the ceiling many points in accordance with the prescribed rules (Fig. 1). By collaboration with teachers and other school employees experiment was carried out. Unfortunately, Copernicus was right in saying that "the sky in Poland is bad, much better is in Italy, because during the course of the experiment the sky was often overcast. In result we were able to carry out six full measurements, ie, mark the three points at different times in one day (Fig. 2).

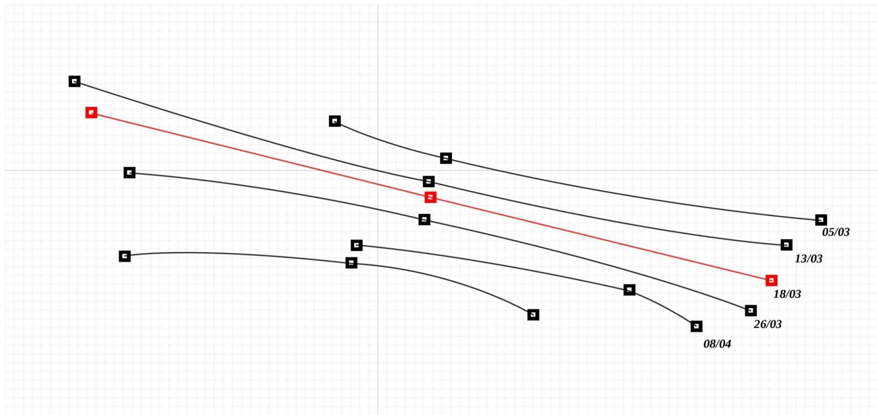


Fig.2. The results of student investigations

3) *The main lesson is a summary of two months of student work and completion of operational objectives through the experience with a lamp and a globe to explain the progressive motion and circulation of the Earth, and the device called in short "gnomon with the lamp" to explain the apparent motion of the Sun and the formation of conical curves. At the end of activities, during the discussion students compare the results obtained by the Persons involved in the restoration of the Nicolaus Copernicus observations with the original charts received at the lesson. Together, we find the important differences:*

- *line (approximately straight line) describing the spring equinox falls on March 18,*
- *hyperbolas are rather clear before equinox, however, subsequent graphs show the number of errors, which we made during measurements or when we moved the observation points to a coordinate system (particularly, the error is evident in the graph dated 8 April).*

Then, we reflect on the causes of the resulting errors:

- *difficulties in marking points: diameter of wheel ("rabbit"), is relatively large, rapid movement of the points - each group marked it in a slightly different way.*
- *transfer of points on the floor. Plumb made by the students was hanging on thin threads and despite the care was not always suspended in a vertical line.*
- *change of the time on the night of 28 to 29 March, which resulted that the marked points have shifted. This is particularly evident in charts when one compares the first measurement of 5.03 – approximately 10.30 hour, and the measurements: the first of 8.04 - about 12.00 and the second measurement of 22.04 - about 12.00.*

  In this way the point of curvature of the hyperbola was not read and for that reason, the curves do not have the expected shapes.
- *weather, overcast sky did not give the possibility to make more measurements, which would verify the other measurements.*

At the end we wonder together how to improve ***Case studies****. At the next lesson during the multimedia presentation the Nicolaus Copernicus Astronomical table was presented to the students (Fig.3.)*

Fig.3. Astronomical table of Nicolaus Copernicus placed at Olsztyn castle

The most imprtant part of this table is the line AEQUINOCTIUM, it means equinox. Three points survived until our time: first, looking like a T lingatura AE, with the upper bar has been drawn, the second – I and the third C.

8. Difficulties in teaching and learning

*During the introductory lesson, the question arises**: how the hyperbolas and straight line indicating the solar equinox appear?** This problem can be explained using a mathematical basis associated with conical curves and trigonometric functions. At the stage of higher secondary schools (engineering secondary schools) it is possible, but at the stage of lower secondary school students do not possess such knowledge.*
*The easiest way to resolve these difficulties is to **perform experiment with "gnomon and lamp**", where young People in an accessible way can learn why the sun during the equinoxes in the Figure 2 is a straight line, and in other cases, the apparent movement of the sun appear hyperbolas (see scenario of the main lesson).*
*Also during this lesson we are making **the first stage of improvement of Case study**, hoping that further observations will better. Students immediately suggested that it should increase the frequency of measurements during the day - especially near the noon hours.*
***Another way** to improve the observation may be to find another idea for a selection of points, eg if the room is large, the points of the so-called "rabbits" will fall out on the ceiling and, if room is narrow - on the opposite wall. If could be possible to construct such plumb, which ensure that the projected points are perpendicular, it also reduced the errors of measurement.*
The next step to remove difficulties in the measurement is to compare the experimental results with those obtained theoretically, calculated and placed on website:
http://epsrv.astro.uni.torun.pl/cgi-bin/magda/sun/sun.cgi

9. Teacher's pedagogical competencies

Until now I and my students haven't known on Copernicus astronomical table. Through involvement in the project HIPST we learned a lot about this Case study. Participating in seminars on this subject and reviewing the relevant historical sources I have gained the skills necessary to carry out the experiment of Nicolaus Copernicus. In addition, besides knowledge
and skills the most important was the enthusiasm of students and others, similar, cooperating with us "hotheads".
I think that a lot of information needed to carry out the above activities you can find in the attached lesson scenarios and presentations.

10. Documentation (certificate) of studies

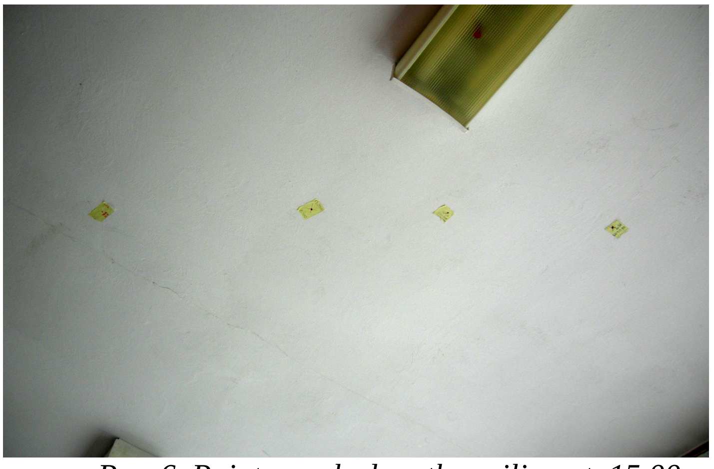
Within this Case study students were actively engaged in work relating to the restoration of the Nicolaus Copernicus experiment. They:
1) marked on the ceiling the points of light reflection at different times:
8.30 (Fig. 4):

Fig. 4. Points marked on the ceiling at 8.30

at 12.00 (Fig. 5):

Fig. 5. Points marked on the ceiling at 12.00

at 15.00 (Fig. 6):



Rys. 6. Points marked on the ceiling at 15.00

2) One student made the apparatus needed to carry out observation - the mirror stand. It was placed on the inner window in the selected point, marked by pencil. Also, the mirror was marked with a pencil point. System needed to make experiment was arranged properly, if these two points marked with pencil were tangential (Fig. 7)

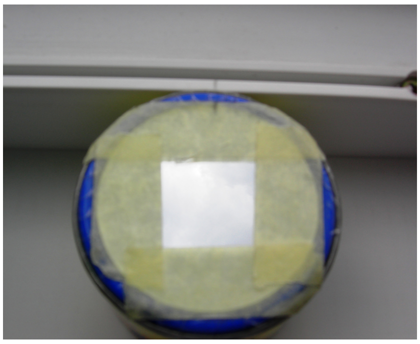


Fig. 7. Experimental setup: parapet - mirror

3) *Students in the following manner marked a point on the ceiling: in the middle, where a clear point (so-called "rabbit") with a diameter of about 5cm appeared they stuck tape and paper, wrote down a cross date and time of measurement (Fig. 8).*

Fig. 8. Point marked by students

4) *During transferring of points from the ceiling the students use the plumb constructed from threads and light bob.*
5) *One student, interested in computer science, developed and made a graph as a result of long, careful work (Fig. 2).*

Unfortunately I was not able to conduct the survey proposed by the project HIPST partners because the Case study began to pursue as early as of 9th February 2009.

11. Further professional development of users

Literature:

1. Tadeusz Przypkowski, *O Mikołaju Koperniku*, PWN, Warszawa, 1953.
2. Tadeusz Przypkowski, *Astronomiczne zabytki Olsztyna*, Muzeum Mazurskie w Olsztynie, Rocznik Olsztyński, vol. II, 1959, str. 135 – 172.
3. Jerzy Sikorski, *Z zagadnień organizacji pracy badawczej i warsztatu naukowego Mikołaja Kopernika,* „Komunikaty Mazursko – Warmińskie",1993, nr 2 (200), str. 131 – 166.
4. Grzegorz Derfel, *Wędrówki słoneczne,* „Wiedza i Życie", 1999, nr 9, str. 70 – 73
5. Agnieszka Witkowska, *Historia doświadczenia Mikołaja Kopernika,* prezentacja multimedialna
6. Zygmunt Turło, Agnieszka Witkowska, Józefina Turło, *O kalendarzu słonecznym Mikołaja Kopernika. Część I,* „Nauczanie przedmiotów przyrodniczych", biuletyn Polskiego Stowarzyszenia Nauczycieli Przedmiotów Przyrodniczych, 2009, nr 29 (1/2009), str. 9 – 17.
7. Agnieszka Witkowska *O kalendarzu słonecznym Mikołaja Kopernika. Część II,* „Nauczanie przedmiotów przyrodniczych", biuletyn Polskiego Stowarzyszenia Nauczycieli Przedmiotów Przyrodniczych, 2009, nr 30 (2/2009), str. 25 – 29.
8. Magdalena Czerwińska, *O kalendarzu słonecznym Mikołaja Kopernika. Część III,* „Nauczanie przedmiotów przyrodniczych", biuletyn Polskiego Stowarzyszenia Nauczycieli Przedmiotów Przyrodniczych, 2009, nr 30 (2/2009), str. 30 – 40.

9. Multimedia presentation at II National HIPST Meeting in Olsztyn 12.09.2009.
10. Honorata Korpikiewicz, *Jak brzmiał tytuł dzieła Kopernika?* „Urania", 1974, czerwiec.

There is possibility to check correctnes of measurements at the Web page:
http://epsrv.astro.uni.torun.pl/cgi-bin/magda/sun/sun.cgi

12. Written literature sources

Lesson scenarios (introductory and main), *Lectures about the sun calendar of Nicolaus Copernicus* and multimedia presentations can be found at **http://hipst.fizyka.umk.pl**
Other items - points 6-9, as above**.**