

## *Description of Case studies: „Studies of Witelo on rectilinear propagation of light” - - for exchange within the HIPST project*

### **1. Title:**

**„Studies of Witelo on rectilinear propagation of light”.**

**Key words:** history of optics, Witelo, replica, experiment, rectilinear motion of light, shadow

### **2. Authors and Institutions:**

**Chojnacka Justyna**, Zespół Szkół nr 4, IV Liceum Ogólnokształcące im K. K. Baczyńskiego, ul. Kaliska 108, 87-800 Włocławek, Polska, [justa\\_chojnacka@o2.pl](mailto:justa_chojnacka@o2.pl) collaboration: Instytut Fizyki UMK w Toruniu, Dr. Józefina Turło, [jturlo@fizyka.umk.pl](mailto:jturlo@fizyka.umk.pl)

### **3. Summary:**

Topics related to the light and its role in nature in the Polish curriculum is divided into topics related to the geometric optics, which only in approximate way describes propagation of light and wave optics, where phenomena associated with the wave nature of light as interference, diffraction and polarization are discussed. Later, in the modern physics, second, molecular (quantum) nature of light is also considered. One of the first - if not the first - theme is the phenomenon of reflection and refraction of light falling on the boundaries between the various media. Most teachers just take this opportunity to talk about the basic assumption of geometric optics – on rectilinear propagation of light and the light itself present in the form of radiating rays. Later, this model of light is used in constructing the images produced in mirrors, lenses as well as in more sophisticated optical instruments. In general, however, the large volume of material that must be achieved within a lesson unit, omitted an explanation of the basis on which the light "emerges" in the form of straight lines or section that is fair view of light rays, as well as physical considerations and observations confirming the validity of this assumption. We take it as certainty (axiom). **So, lacking in our curriculum introductory lesson to geometrical optics!** Lessons, during which the students themselves could conclude on rectilinear motion of light, and the consequences of such motion.

Aim of this lesson would be also illustration, as sometimes long way leads from the observation of the phenomenon to drawing the correct conclusions, showing its explanation.

The shadow is accompanied by the People "always". Probably many a time was asked what is the reason for its creation and what are the conditions on which his "look" depends. The discovery - the shadow of light arises because the light in the homogeneous space move along straight lines – drew out Witelo, but only in the thirteenth century.

This subject can and should be implemented at both (lower and higher) secondary schools and at every level of education.

### **4. Description of Case study**

Lesson, which the theme is "Studies of Witelo on rectilinear propagation of light" (Scenario - see Annex 1) in the form proposed by us, has been carried out in the second class of higher secondary school (adolescents of 18 years) with mathematical - physics profile.

Essential part of the lesson was preceded by the fulfilment of the student survey, in which they had the opportunity to comment on: what about is science, whether and to what extent are they

aware of the fact that the achievements of science are used almost everywhere, who is a scientist for them, what is his style of work and what are the conditions of the scientific work. The results of the survey, together with student developments can be found in Annex 3 (Nature of Science - NoS Questionnaire).

Fundamental lesson was divided into two parts: the first - in which using replica of Witelo equipment and today known methods we evidenced the rectilinear propagation of light, the second - during which we were acquainted and also "played" with the consequences of such phenomenon.

Lesson itself proceeded as follows. Students after completing the survey were familiar with the figure Witelo. For this purpose, not to spend too much time on Witelo CV, but only indicate its importance for the world of science, a multimedia presentation was used (Annex 2- in Polish so far). Teacher is asking a few questions like: What is light? What its sources you know? In this way the teacher is trying to determine the level of knowledge of students on the topic, errors in reasoning, and expression of the understanding by students. Afterwards, the students are familiarize with the definition of light and the light ray given by Witelo. The students pay attention to the archaic language of these definitions. Using a laser pointer, and an aquarium containing water with dissolved in the drops of milk shows that the light in the homogeneous media, if does not encountered any obstacles, propagates in straight lines. To show that not only the laser light (which is collimated and targeted beam), but also light from the continuous source runs rectilinearly, we reconstruct the original experiment of Witelo. This experiment is carried out independently with two pairs of students, other students are watching, drawing conclusions. A simple consequence of the rectilinear propagation of light is the formation of a shadow, what was also the subject of Witelo. research. Willing, the students played the role of researchers I divided them roughly into equally-numerous groups. Each group have been equipped with various light sources (spotlights and continuous), transparent and not transparent objects of all sizes and shapes, etc. Using the above. instruments they had to answer the questions: What is the shadow? "Where we see it?, What determines the intensity of the shadow?, What is a penumbra?, What determines the number of formed shadows? Is the phenomenon of the shadow and penumbra related to the sun or the moon eclipse observations?

Active, enquiry work of students during the lesson has been documented by them, while by the teacher's positively evaluated. Pupils discovery was that they fill very well in the role of "researchers", "fun" with shadows caused them a lot of fun. At the end of the lesson they reported the need for more frequent lessons organised in this way.

## **5. Historical and philosophical background, including the Nature of Science**

Witelo was the first in the history of Polish scholars (such as historical sources indicate - he was the son of Poles and Turyngian). The first, and once one of the greatest in Europe in the thirteenth century. Was one of the closest leading contemporary intellectual elite and his works were known to Nicolaus Copernicus, Johannes Kepler and Leonardo da Vinci. Thirteenth-century deep Middle Ages - a time of superstitions, prejudices, witches, demons and devils. However, as the case of Witelo and others like him, became a time fascinated by the logic and Aristotle's rationalism. Indeed, for Witelo empirical facts were more important than intuitive studies.

Both the political situation in the country, as well as generally accepted belief, rising to the highest rank of the church, were not conducive to the development of Witelo, who had just started his studies at the University of Paris. There he met St. Thomas, who as himself was an advocate of

the theory of Aristotle. At the same time at the University of Paris taught St. Bonaventure representing the other side of the ideological barricades. Ultimately, however St. Bonaventure, but not St. Thomas instilled young Pole his fascination with light. Witelo since then he had his own theory of the mechanism and the physiology of vision, particularly his own theory of the formation of optical illusions, writing that "the eye does not receive any other information outside the light, colours and size of the angles, but only the mind is processing impressions with the help of performances taken from the experience". Witelo used the advantage of his theory, without reference to the "satanic power" for explaining the event that took place in his homeland. Well, gray dawn, a certain Henry Cat profession knight, while hunting for wolves in the woods of Legnica saw a wolf the size of the wall of forest. Gigantic beast ran into pig strapped as the bait near the trap. Knight Cat, although "in great fear", but managed to remain in position long enough to see an extraordinary thing - the wolf as he approached the pig, was smaller and smaller, and when the victim was already at him become of natural size. Witelo pointed out, that the observations were made at very low light (dawn), which has prevented proper evaluation of the distance. Hence, there was an optical illusion, resulting from a deficiency of information received by the eye.

Serious scientific work on optics, Witelo started at the Papal court - during the conclave after the death of Pope Clement IV. As the result of that work, a work of life of Witelo "Perspectivorum libri decem" was created. In this Book the contemporary knowledge in the field of optics Phenomena: the rectilinear propagation of light, its reflection, refraction and dispersion were discussed in a precise way, that is most closely based on mathematics and geometry. Witelo in the work "Perspectivorum ..."describes a devices that served him to obtain an empirical knowledge on physical phenomena, in particular a device by which in a simple, though ingenious way he has proven rectilinear propagation of light.

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

The target group are students of all types of schools at every level of education. This lesson can be done also in extracurricular activities, such as the physics circles. Study of rectilinear propagation of light as well as "shadow party" creates an opportunity to make it one of the elements of interactive exhibitions arranged in the exploratory or technology museum. The lesson has inquiry character, ie: students do their own historical experiment demonstrating a straight run of light and looking for simpler, more modern methods of presentation. Performing simple experiments with a shadow they are answering the questions: When is the shadow coming into existence? Why does it arise? A Where a shadow arises? What determines "look" and the number of emerging shadows?

The lesson is a fun, during which the following concepts are assimilated: a light beam, a stream of light, shadow, penumbra, and also in a qualitative way the phenomena of solar and the moon eclipses are explained. Pupil doing their own experiment ceases to be real doubt whether the light propagates in straight lines, which is relevant in its further studies. Introducing of the historical elements aims to encourage students to learn "from bases", stretching to the beginning, the first things, the basic concepts and definitions. We think that only then knowledge of students will be complete and reliable.

## **7. Activities, methods and tools of learning**

### **Teaching Methods:**

- based on the word,

a talk - presentation in a clear and transparent manner of the necessity to conduct research by Witelo in optics, and to quote some definitions, postulates and theorems formulated by him,

- **based on the observations and measurements,**

demonstration and measurements – repetition (with details) of the Witelo experiment Witelo by two pairs of students, reading the results and drawing appropriate conclusions

**Educational tools:**

- a copy of the presentation device of Witelo (replica) for rectilinear propagation of light,
- multimedia projector, computer, ppt presentation,
- overhead projector, a sample of transparent and not transparent items,
- three light sources (candles, light bulbs),
- three different sizes of balls or round fruits,
- board, chalk.

## **8. Difficulties in teaching and learning**

Lesson conducted in the project HIPST was preceded by a survey in which students demonstrated knowledge related to the science and scientists, as well as have the opportunity to identify their relation to science, popular –scientific and the scientific literature, etc.

Fundamental lesson was a fun. Students correctly answered questions and formulated their own conclusions and proposals related to the made observations. Demonstrated also the creativeness in the search for modern methods of presentation rectilinear propagation of light. A little problem was with the historical experiment of Witelo, where we used continuous source of light. Students didn't know that as a consequence of rectilinear transmission of light, after removing the obstacle from the Witelo device, width across the beam on both sides of the hole in the wall of cylinder will increase the same. This difficulty can be solved by enriching experiment with simulation, replacing the beam of light in the original experiment by the rays in the computer simulation.

After the lesson, Questionnaire (on NOS), which has been previously completed was repeated.

## **9. Teacher's pedagogical competencies**

To carry out a similar lesson does not require any additional capacity or skills, but only those which are necessary to work as a teacher. Everything what decided to undertake our tasks, the mission of learning and teaching others is completely enough here. Little difficulty, can make only the construction a replica of Witelo device. To achieve the desired results we can use just the simplified version of this instrument – e.g. the paper cylinder with indicated on its inner side the angle in degrees, a pair of concentric holes in the walls of the cylinder and small block with small holes at an appropriate height. Necessary is also an appropriate source of light.

## **10. Documentation (evidence) of studies**

Documentation of the survey research is eg. awareness studies of students on the use of science in everyday life, the need for scientific research as well as the impact of determinants of the age in which scientists are living on the process of creation – discovering.

## **11. Further professional development of users**

1) L. Bieganowski, A. Bielski, R.S. Dygdała, W. Wróblewski,

Witelona Perspektywy Księga II i III, Wydawnictwo Polskiej Akademii Nauk, 1991,

2) A. Bielski, L. Bieganowski, Studia i Materiały z Dziejów Nauki.

3) J. Turlo et al, Europejski projekt FP7 HIPST, Nauczanie Przedmiotów Przyrodniczych, 30/2009, ss. 41-48

## **12. Written literature resources**

**1) Scenario of the lesson on: Studies of Witelo on rectilinear propagation of light”.**

**2) Multimedia presentation – „Studies of Witelo on rectilinear propagation of light ”ppt,**

**3) Analysis of Questionnaire on Nature of Science**

4) Description of Case studies” on the same topic,

5) Paper J. Chojnacka, on: „Studies of Witelo on rectilinear propagation of light”- proposition of inquiry based lesson within HIPST project, Science Teaching, No 32/2009, pp. 16-22 .

6) Multimedia presentation at the II National HIPST Meeting in Olsztyn 12.09.2009.

**Scenario of the lesson on:  
Witelo's studies on rectilinear propagation of light.**

**Justyna Chojnacka**

Zespół Szkół nr 4, IV Liceum Ogólnokształcące im. K. K. Baczyńskiego,  
ul. Kaliska 108, 87-800 Włocławek

**General aims:**

— cognition of assumptions that determine the light description in geometrical optics,

**Specific aims**

Student:

— knows historical reasons motivating to search the answers to the questions connected to human's perception, vision of the world,  
— understands potrzebę the need to create and refine the new physical concepts and to formulate and prove the theorems,  
— understands the weight of proving the theorems empirically,  
— recognizes, by studying the certain fragments of Witelo work, the evolution of the ideas,  
— knows the basic assumptions of geometrical optics,  
— is able to describe the course and explain the result of the historical Witelo's experiment,  
— explains the formation of shadow and penumbra,  
— knows under which conditions we observe the Sun and Moon eclipse,  
— indicates the areas of everyday life, in which we use the shadow and penumbra phenomena.

**Educational methods:**

- *based on words*,  
talk – clear and transparent presentation of the need to conduct optics studies by Witelo, also quotation of some definitions, postulates and theorems that he formulated,
- *based on observation and measurement*,  
demonstration and measurement – detailed repetition of Witelo experiment by two pairs of students, deriving the results and proper conclusions.

**Educational tools:**

- copy of Witelo's device for demonstrating the rectilinear propagation of light,
- multimedia projector, computer,
- overhead projector, sample transparent and opaque objects,
- three sources of light (candles, bulbs),

- three balls of different size or spherical fruits,
- table, chalk.

### **Forms of work:**

- individual,
- 5-person groups,
- homework.

1) Teacher's welcome, write of the lesson's subject and short information about the meeting's aims.

## **INTRODUCTION**

Witelo was one of the most famous Polish scientists. He stretched his research on almost each science segment, that is why his subsequent works created the unity with everyday life elements. His work „*Perspective*” which might seem devoted to optics, one of physics' branch, is also the basic geometry work. It also deals with human physiology, one chapter is an eye description with its mechanisms. Witelo took into account the subconscious action of mind, its influence on „seeing”. There were many interests in Witelo's activities, he was not only the naturalist, but also mathematician and philosopher.

During our physics lessons, we will limit ourselves to tracing Witelo's way of thinking, which lead him to formulate subsequent theorems and some experiments fundamental for geometrical optics (slide no.2 from the presentation - Fig.1.).

Witelon, także: Witelo, Vitellio, Vitello, Vitello  
Thuringopolonis, Erazm Ciółek (ur. ok.1230 -  
zm. między 1280 a 1314)

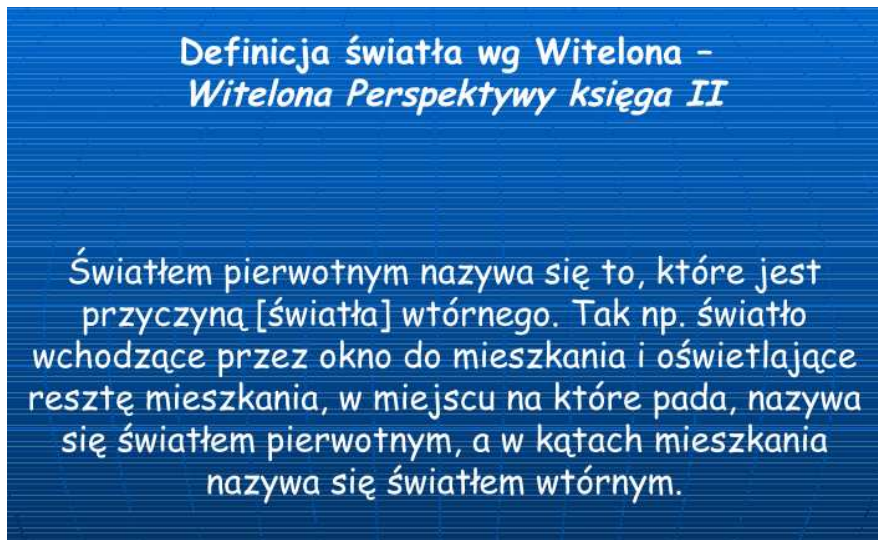
Syn Turyngów i Polaków

Działający w XIII wieku Witelo, jeden z najwybitniejszych uczonych europejskich epoki średniowiecza, zwany także Witelonem, Vitellio, Vitello lub nawet Erazmem Ciółkiem, był pierwszym Polakiem, który zyskał na polu nauki sławę europejską.

O znaczeniu jego prac niech świadczy fakt, że były one czytane, cytowane i uzupełniane w następnych wiekach m.in. przez takie sławy jak Mikołaj Kopernik, Leonardo da Vinci, Izaak Newton czy Johannes Kepler.

**Fig.1.** Slide no. 2 of the presentation.

	<b>Teacher's activities</b>	<b>Student's activities</b>
	1. Teacher questions: What is the light?	- The light is the visible range of electromagnetic spectrum (electromagnetic wave),  - collection of particles – photons, each carrying his own energy
	2. Teacher shows the definition of light by Witelo as the next slide of the presentation (Fig.2.).	- students notice the archaic way of formulating the definition,



**Fig.2.** The definition of light by Witelo.

	3. What do we call the source of light?	- the sources are all radiating objects,
	4. What is the way of light propagation?  What is the way to observe it?	- rectilinear one  - laser's beam, shadow
	5. Introduces the definition of light ray and light beam: while observing the Sun Witelo assumed, that the light propagates linearly as rays. Due to Witelo we can see the light only when it has the certain width (the lines along which the light propagates have a certain width). In the middle of the line there is a symbolic mathematical line, or the minimal visible portion of light. All the other light lines are parallel. The set of the parallel rays is the light beam.  It is the first assumption of geometrical optics: The light stream	



is a collection of separate, individual rays.	
6. Shows the pictures on which you can notice, that the rays are rectilinear (Fig.3.).	- they notice, that the rays on the pictures are rectilinear,



Fig.3. The slide which shows the rectilinearity of light.

7.Presents the Witelo's theorem about rectilinear propagation of light (Fig.4.).	- read the content  „[Exiting of] the rays from any light source and propagating of the forms takes place linearly. The above statement can be proved not by evidence, but using a device.”
--	---

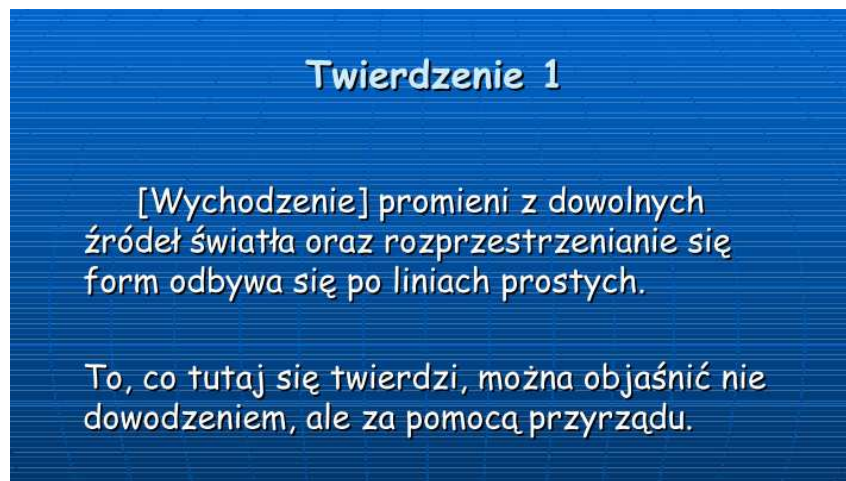


Fig.4. The slide presenting Witelo's theorem on rectilinear propagation of light.

	<p>8. Demonstrates the exact copy of the device, which was used to prove the rectilinear propagation of light. There is a scheme to redraw for the students (Fig.5.).</p>	<p>- the student describes the device:</p> <p>The device is an empty cylinder of concealed bottom. There is a degree scale on the inner side of the cylinder. There are two identical holes (2-3 mm wide) on opposite sides of the cylinder's wall. These holes are on the same height (2-3 mm) from the bottom of the device. Inside the dish there is a flat-plate parallel with the same hole as the ones drilled in cylinder's walls. The plate is attached to the bottom. This way all the holes are located on the same line, perpendicular to the cylinder's axis.</p>
--	---	---

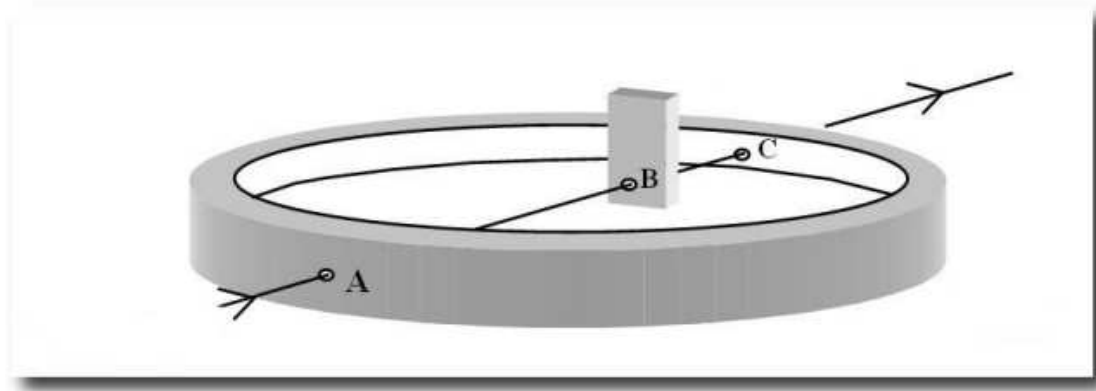


**Fig.5.** The slide with the scheme of the device for measuring the rectilinear propagation of light

	<p>9. Explains how to perform the experiment.</p>	<p>- two pairs of students perform the experiment, derive the results (determine the beam's width), the other formulate the conclusions,</p>
--	---	--

**EXPERIMENT:**

We put the light source next to one of the holes. The light is coming into the plate's hole and then on the cylinder's wall creating a circle spot there.



**Fig.6.** The scheme of the device, which was used to document the rectilinear propagation of light.

**OBSERVATIONS:**

There is a circle spot of light on the cylinder's wall, the middle of the light circle covers the next hole (marked C). We can determine the beam's width on the inner cylinder's wall and notice that the width is the same on both sides of the hole.

**CONCLUSION:**

The line along which the light ray goes crossing both holes A and B and then the middle of the light circle C is located on the plane and creates the circle's diameter. The circle's diameter is a straight line.

	10. Formulates the second assumption of geometrical optics: The light rays go rectilinearly from the source up to the moment when they meet the obstacle or there is a change of the environment in which they propagate (Fig.7.).	- writing,
--	--	------------

## Główne założenie optyki geometrycznej:

Promienie światła biegną prostopoliniowo od swego źródła do momentu w którym napotkają przeszkodę lub nastąpi zmiana ośrodka, w którym się rozchodzą.

Fig.7. The slide describing the second assumption of geometrical optics.

	11. The formation of the shadow is one of the consequences of the rectilinear propagation of light.	
	12. Devides the students into 5 groups. Each group has its own set of props to demonstrate other phenomena. The teacher (T) asks the questions, the students (S) answer.  Each conclusion derived from the experiment is displayed on slides as the theorem formulated by Witelo a long time ago. (Fig.8.).	

## Cień

1. W nieobecności światła powstaje cień (Post.3).
2. Z pojawieniem się światła znika cień (Post.4)
3. Cień ciała nieprzezroczystego bardziej oddalonego od ciała świecącego jest mniej intensywny, bliższego bardziej (Tw. 31).
4. Światła i barwy w ciałach przezroczystych nie mieszają się wzajemnie, ale przenikają [je] oddzielnie (Tw.5).
5. Jeżeli średnica kulistego ciała świecącego jest większa od średnicy oświetlanego ciała kulistego, to oświetlona jest więcej niż połowa ciała, a podstawa cienia jest mniejsza od wielkiego koła ciała oświetlanego, [a linie ograniczające cień ] przecinają się w jednym punkcie za ciałem (Tw.26-29).

Fig.8. The slide containing the experiment's conclusions.

### ***Experiment 1***

Students demonstrate the shadows of different size and shape. They change the distance between the light source and the object.

T: What is the shadow? Where is it formed?

S: This is an area not available for the light.

T: Would it be possible to get the shadow if the propagation of light is not rectilinear?

S: No, because each area could be lighted.

T: When is the shadow more intensive, when is it weak?

S: The closer the object gets to the light source, the more intensive is the shadow.

### ***Experiment 2***

We point the light beam from the projector on the object:

a) transparent,

b) opaque.

T: What do you observe?

S: The shadow arise if we direct light on opaque object. We don't get the shadow if the light is directed towards the transparent object.

### ***Experiment 3***

We illuminate the same objects as in Experiment 1 with two light sources or one extended source.

T: What do we observe?

S: We observe the fuzzy shadow, that means stronger in the shadow of both sources and weaker around – in the area we call penumbra.

T: How does penumbra arise?

S: One light source illuminating an opaque object is causing its shadow. At the same time this area is lighted by the second source, hence the penumbra effect.

### ***Experiment 4***

We illuminate an object by three light sources.

T: How many shadows arise?

S: Three.

T: What does the number of shadows depend on?

S: On the number of light sources.

T: Are there any natural phenomena connected with the umbra and penumbra?

S: Yes, solar and lunar eclipse.

### ***Experiment 5***

Demonstration of solar and lunar eclipse by setting the balls or fruits of different size in the correct order.

2) The teacher summarizes the lesson, providing the homework: Is there „something” (person, animal, object) which under favorable conditions, does not have the shadow? Answer.

**BIBLIOGRAPHY:**

- 1) L. Bieganowski, A. Bielski, R.S. Dygdała, W. Wróblewski, *Wielona Perspektywy Księga II i III*, Wydawnictwo Polskiej Akademii Nauk, 1991
- 2) A. Bielski, L. Bieganowski, *Studia i Materiały z Dziejów Nauki*,

**Questionnaire analysis related to the lesson:  
“Witelo’s studies on rectilinear propagation of light”**

by Justyna Chojnacka

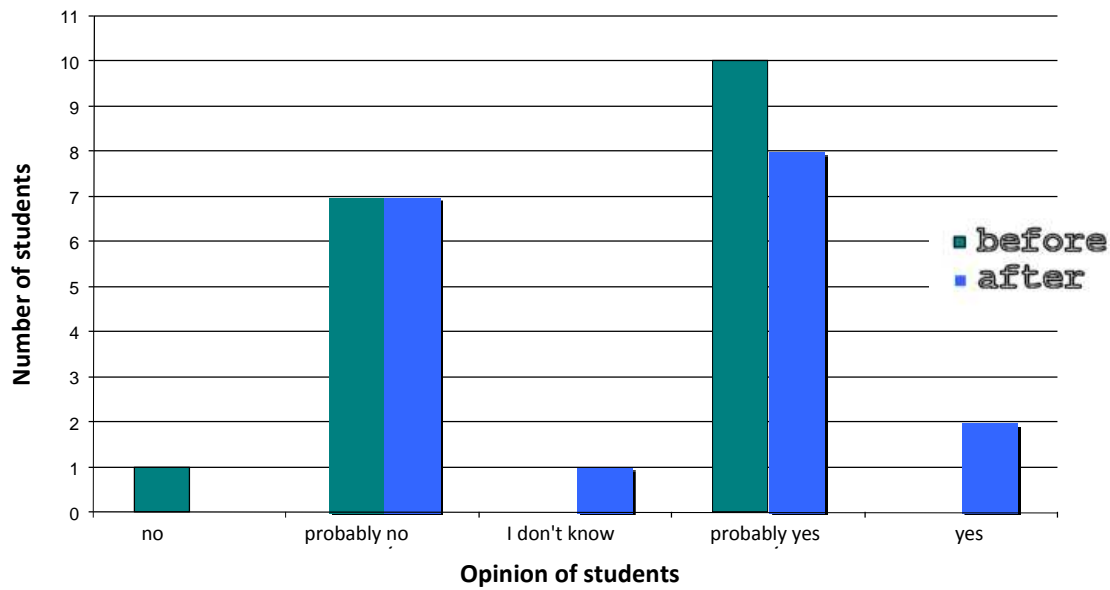
The *Questionnaire* that was recommended to complete before and after conducted lesson has been prepared within the framework of international project HIPST. The questionnaire is divided into two parts. The first part consists of questions such as: what is science, what are the conditions of the scientific work, who is a scientist, whether the students are aware of the fact that the achievements of science are used in everyday life. Students respond to the individual questions using the Likert scale choosing from among five items: *No (strongly disagree)*, *rather No (disagree)*, *I don’t know (neither agree nor disagree)*, *rather Yes (agree)*, *Yes (strongly agree)*. The second part consists of 15 affirmative sentences each one describing two types of People. Students had to determine with which type they identify. They had two options to choose: the type of person who describes me either moderately or strongly. Students completed the Questionnaire twice: before and after the lesson.

The questionnaire has been carried out in the second class of higher secondary school (adolescents of 18 years) with mathematical - physics profile. In total, it was completed by 18 People, including 13 men and 5 women.

Below, I insert a chart with a brief commentary, illustrating how the attitude of students towards the science and scientists has changed after the lesson: "Studies of Witelo on the rectilinear propagation of light". The first than the second part of the questionnaire will be discussed.

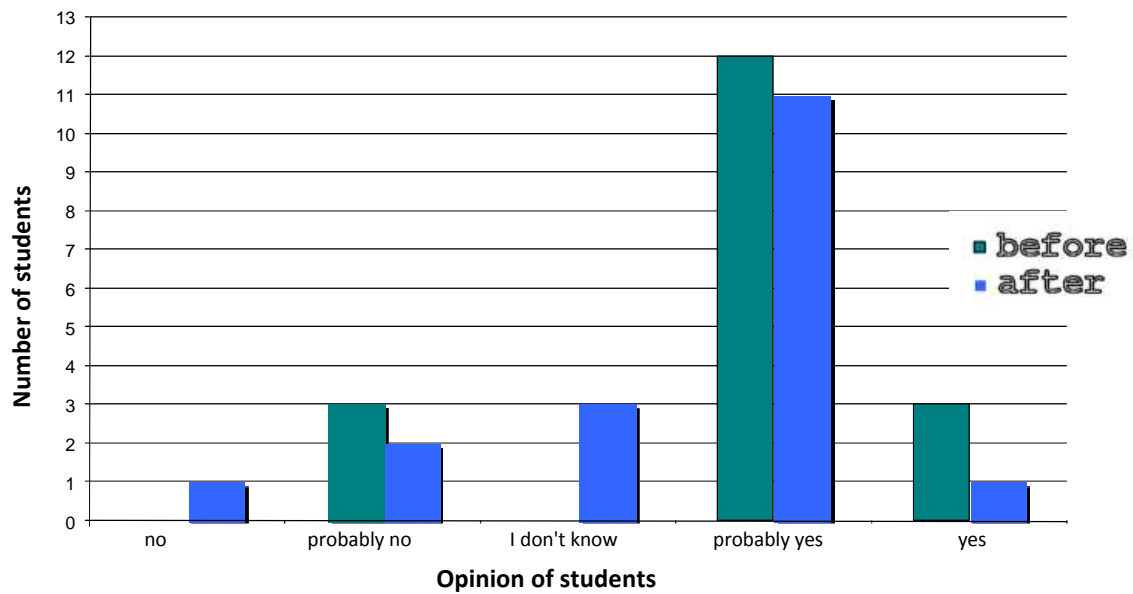
Part one contains 22 statements divided into 3 subgroups: those concerning science, its universality, scientists and their conditions of work as well as our impact on discoveries made and research work. Students ticking the box determined consistency (or inconsistency) with the opinion stated in the sentence. The first subgroup consists of 11 sentences such as: “In science, most of the questions have only one correct answer, Science helps us understand the world, In science the truth is always the same, Science is only for men/women”.

Before the lesson on rectilinear propagation of light 10 out of 18 pupils stated that in science rather most of the questions have only one correct answer and only one person was strongly against. After the lesson the students view of this fact has not changed significantly (Fig.1).



**Fig.1.** Trends presented by students concernig the statement: „In science, most of the questions have only one correct answer”

Almost every student ( before the lesson 12 out of 18, after the lesson 11 out of 18) believes that the contents of the scientific books are true. There is one question remaining: are the students able to distinguish scientific books from popular- science and pseudo - science and the truth contained in which of them they consider to be unquestionable (Fig 2 ).



**Fig.2.** Trends presented by students concerning statemen: „If you read something in the scientific book – that is true for sure.



Students are aware that science allows us to understand the world and makes our lives easier and more comfortable. 16/18 students find science explaining the processes occurring on Earth and in the Universe (Fig 3,4).

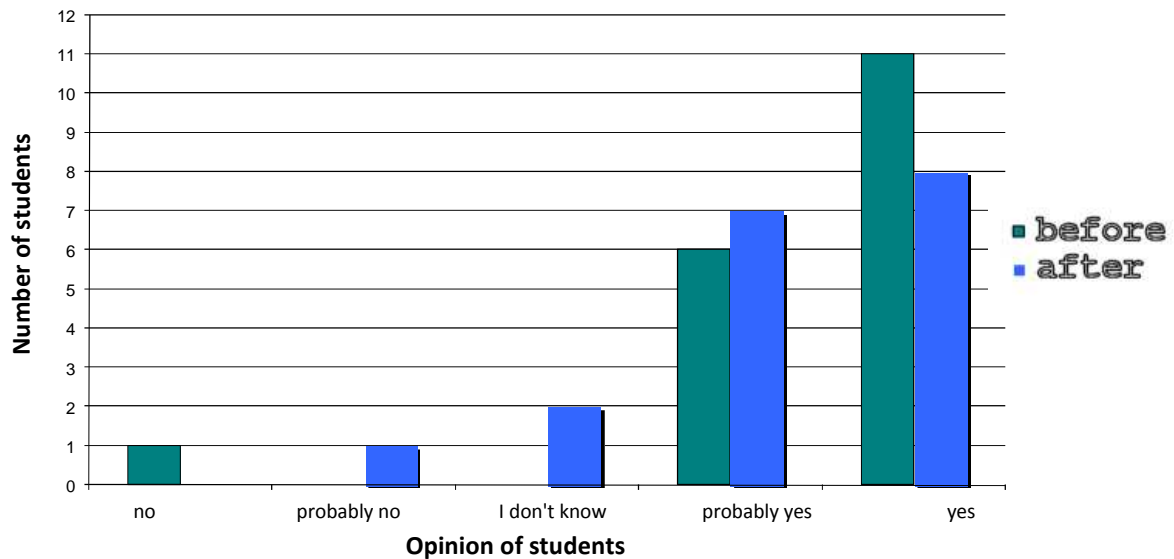


Fig.3. Trends presented by students concerning the statement: "Science helps us to understand the world"

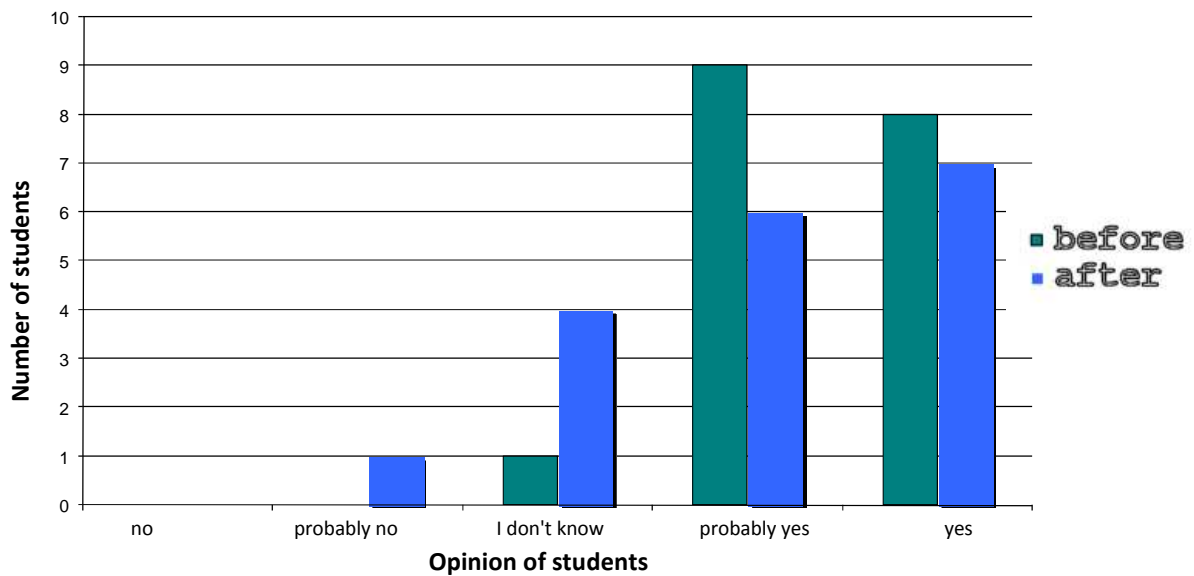


Fig 4. Trends presented by students concerning the statement: "Science helps make our life happier and much more comfortable".

Enjoying is the fact that students do not identify science with only one gender e.g. they assume that a good scientist might be both a man and a woman. Nevertheless, it can be seen that a more specific answer on this issue was granted before the lesson. Results of the questionnaire conducted after the lesson on Witelo are more scattered in other answers, although still indicate equality between men and women. It is probably due to the fact that it was the boys that showed greater brilliance, creativity and curiosity than girls. (Fig 5,6).

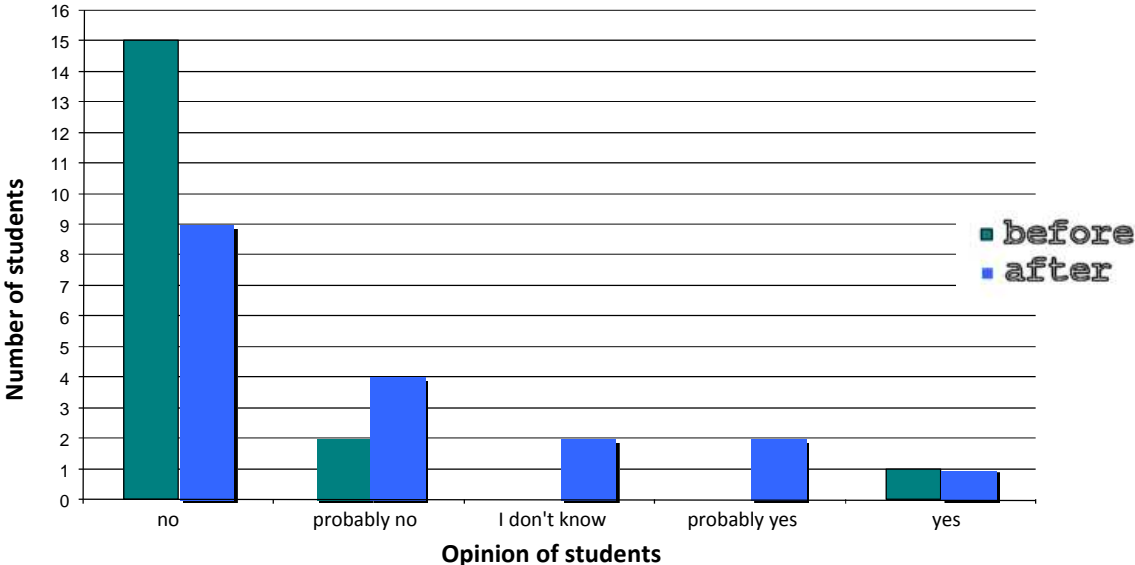


Fig.5. Trends presented by students concerning the statement: „Science is only for man”

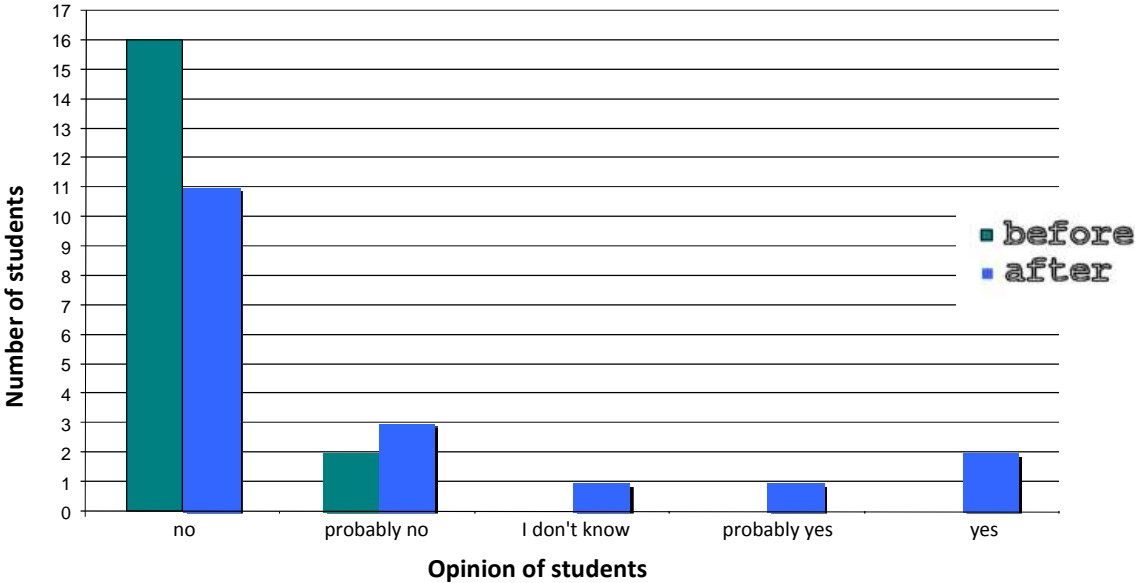


Fig.6. Trends presented by students concerning the statement: „Science is only for woman”.

Surprisingly, according to 11/18 students science is not only for gifted people. After participating in individual scientific work the number dropped to 4/18. (Fig 7)

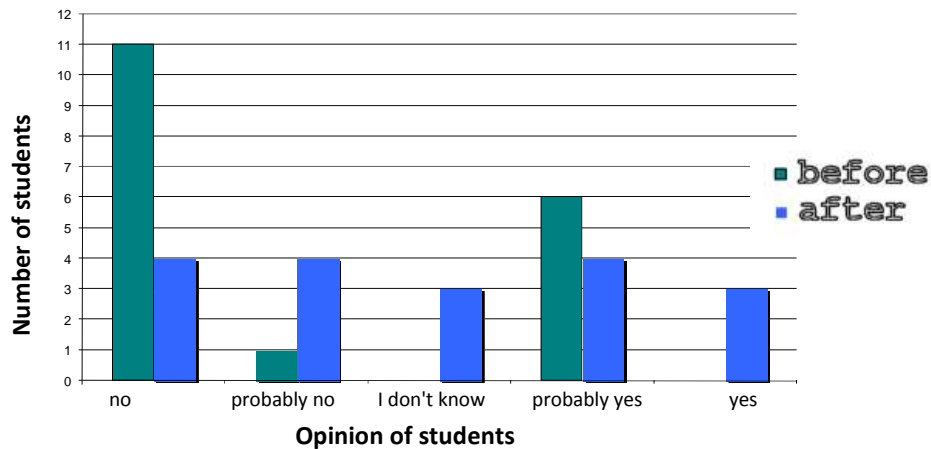


Fig.7. Trends presented by students concerning the statement: „Science is only for gifted students”

Sentences in second subgroup are connected to scientists, their work circumstances and applied research methods.

Students show a rather poor knowledge of scientists lives. They do not realize that national policy, the economy, financial situation as well as place of residence, etc. have great influence on their development. That explains a great number of answers – neither agree nor disagree.

After presenting the situation in medieval (superstitious) Europe, a strong impact of the Church on the science and scientists, and how Witelo’s views on many issues differed from generally accepted, the pupils realized that the way we live and how we live influence the way we reason (Fig 8,.9).

Students generally assume that scientists conducting research use different scientific methods and conduct research using different methods so they can explain one thing in a variety of ways. (Fig 10,11)

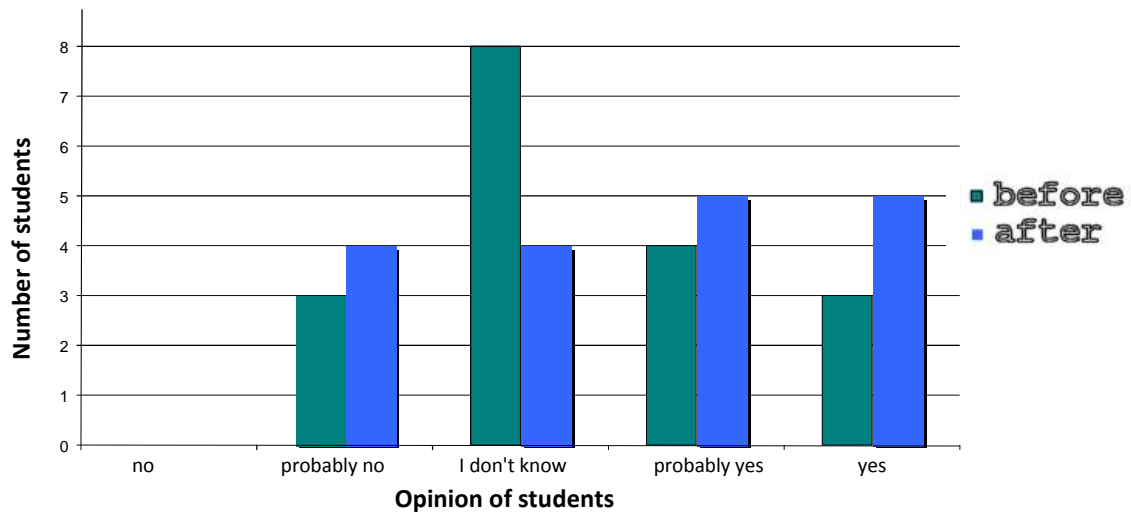


Fig.8. Trends presented by students concerning the statement: „Scientists are influenced by the conditions of their life: economy, religion, art”.

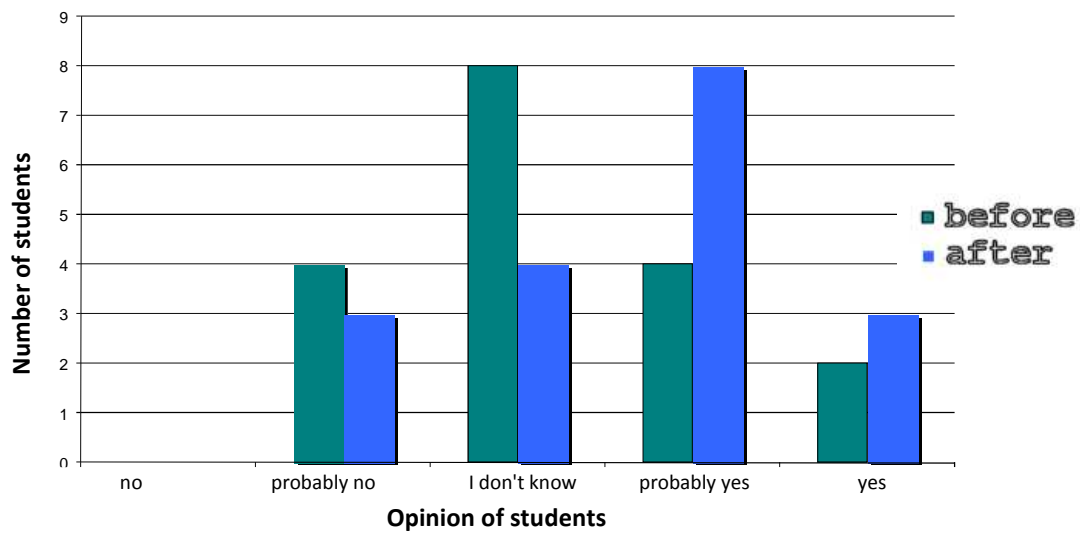


Fig.9. Trends presented by students concerning the statement: „ Scientists are influenced by the ways they live. For example through their families, financial situation, place of living”.

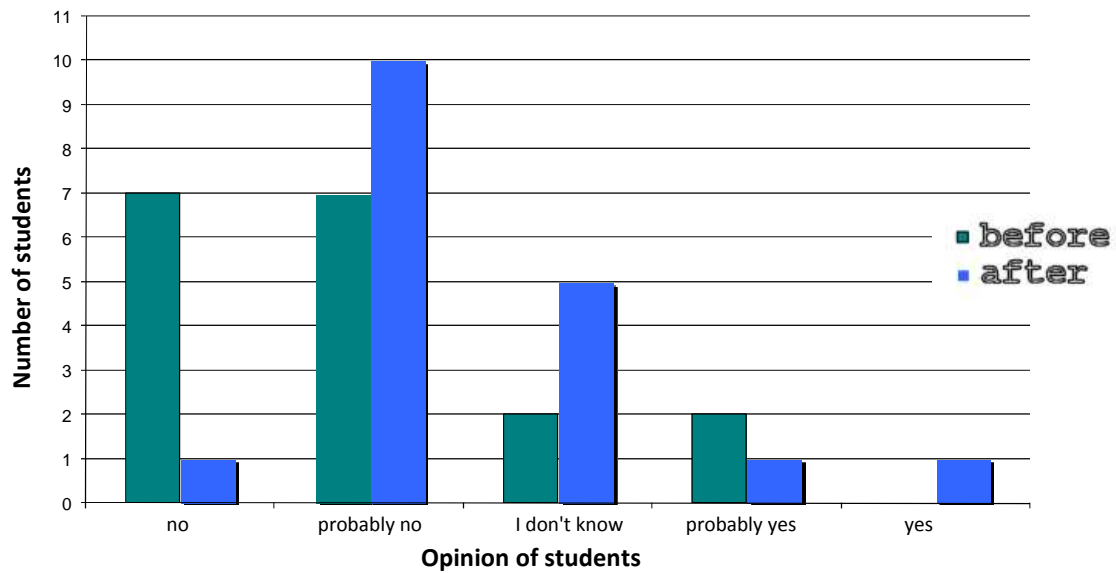
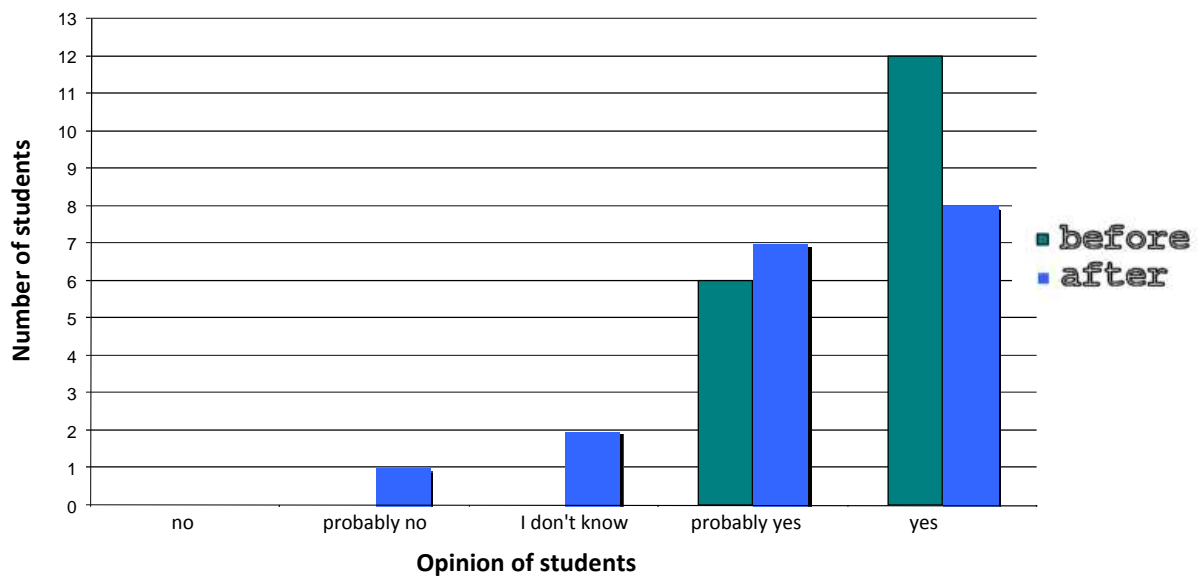
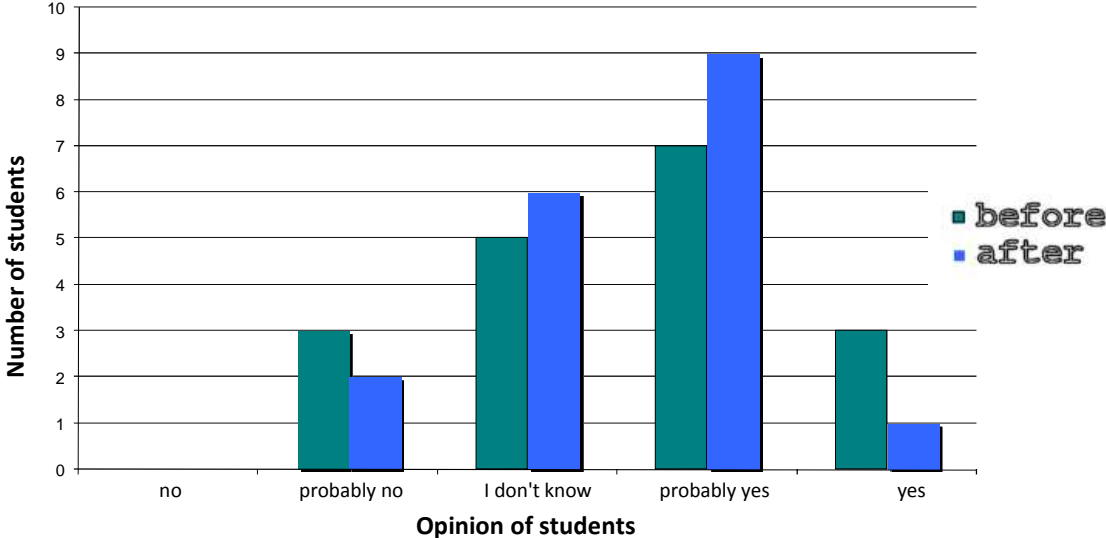


Fig.10. Trends presented by students concerning the statement: „ All scientists conducting research use the same scientific method”.

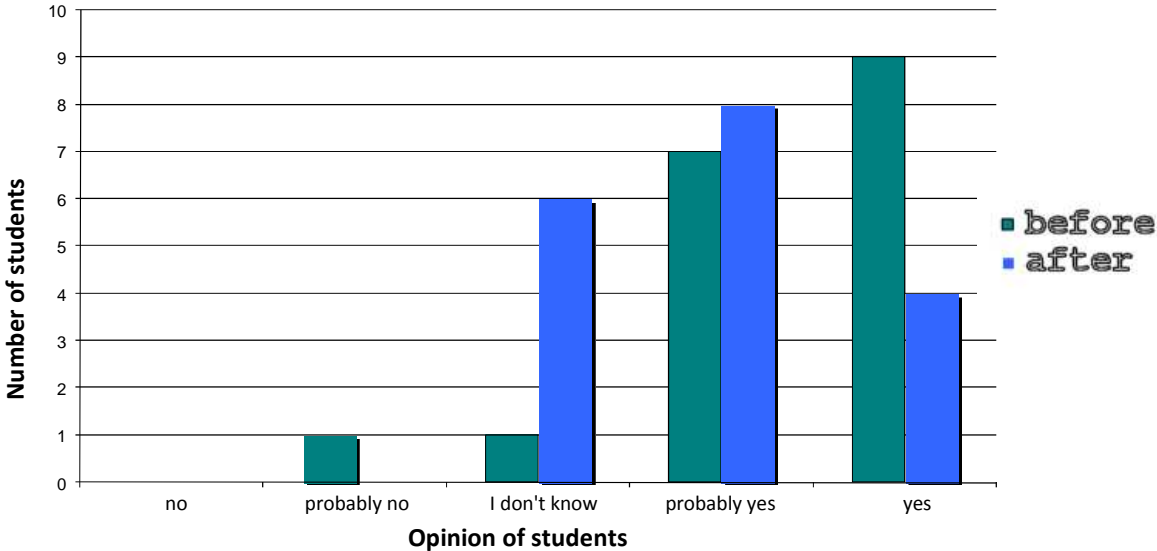


Rys.11. Trends presented by students concerning the statement:” Scientists conduct research using different methods”.

Sentences from 18 to 22 indicate the degree of people’s awareness that science or rather its achievements are used by us every day and that to a large extent we influence what the research are conducted on suggesting the need for a specific technique, technology, etc. (Fig. 12,13).



Rys.12. Trends presented by students concerning the statement:., The way scientists are conducting research is fluneced by needs of other People.



Rys.13. Trends presented by students concerning the statement:., All of us are responsible for the way of using results of scientific research in the everyday life”.

The second part of the Questionnaire consists of 15 statements describing two types of People. Students by ticking box determine the extent to which they identify with the types of People: moderately or strongly. Sentences describing particular types of People do not differ much from each other, they revolve around the same topic: Do students demonstrate the independence in discovering law of nature? Hence, my general summary of the second part of the questionnaire.

Students ( adolescents of school age) like self –reliance when working on the lessons of natural science. 15/18 people pointed out that sentence concerning the independence of working on lesson described them perfectly. They demand teacher to engage only slightly by establishing the research topic. At the same time, students are willing to work as a team - 14/18 students announced after the lesson that this type of person described them. It is easier for them to discuss, call into question the observations made or draw conclusion in a group of their peers rather than discuss them with their teacher. For young people, for whom the natural science is not a favorite course, the ability to independently carry out simple “scientific” research is a big challenge and great fun. Lessons in which students make their own experiments are for most of them attractive. At the same time making an effort of experiments students realize how difficult it is sometimes to understand anything related to science.

The following charts (Fig.14,15,16) show the trends among the students described above.

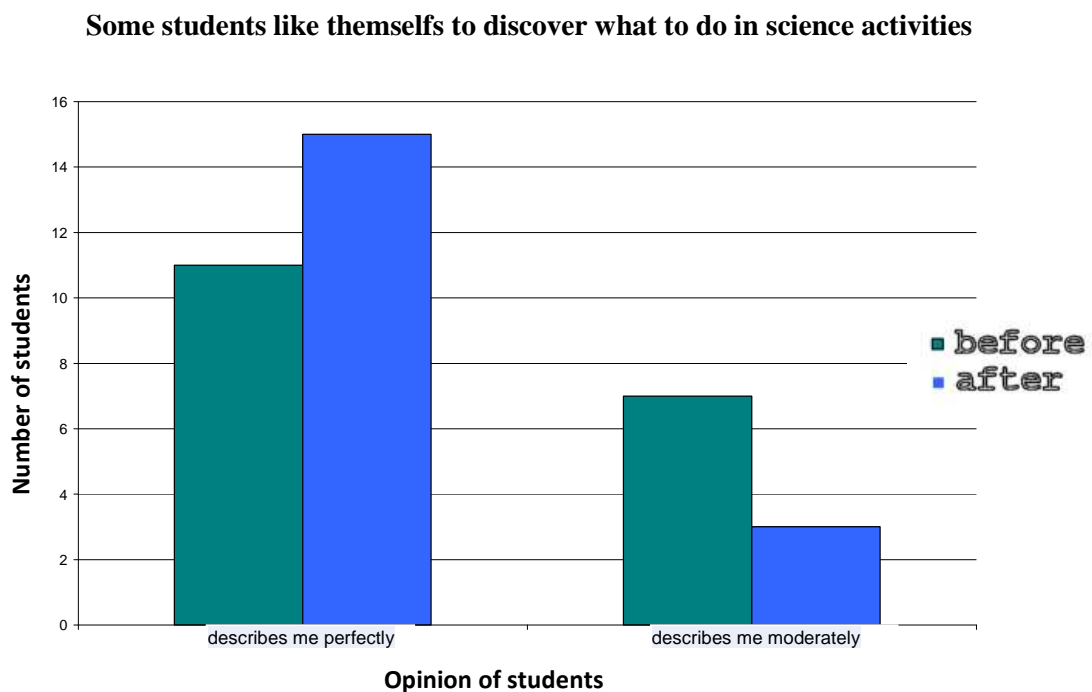


Fig. 14. Trends presented by students related to self-reliance work during the lessons

### Students like to work with colleagues in the scientific activities

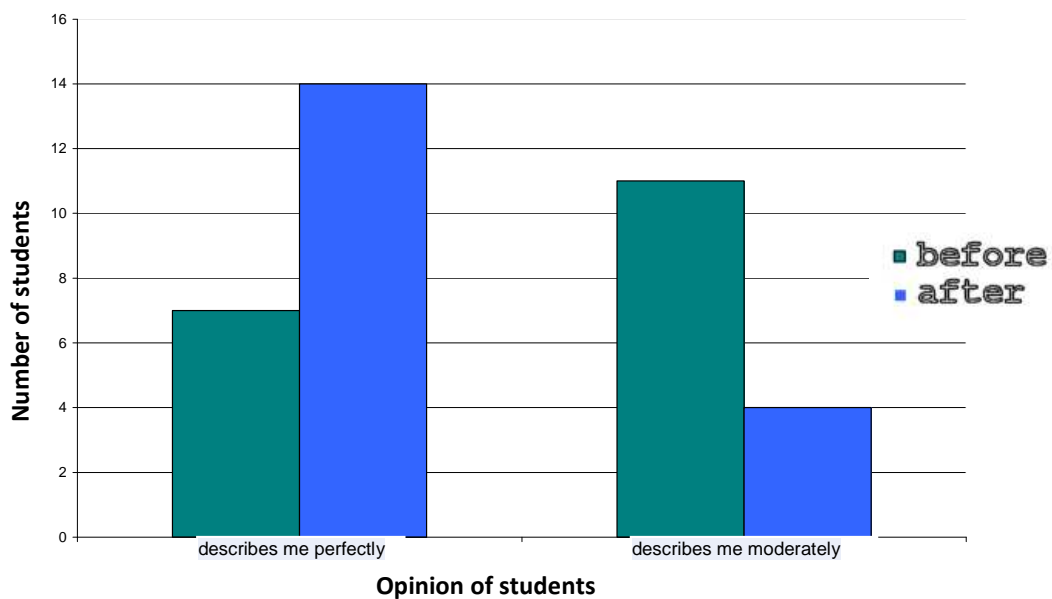


Fig.15. Trends presented by students related to working in team at science lessons.

### Students like to discuss their ideas with colleagues during the scientific activities

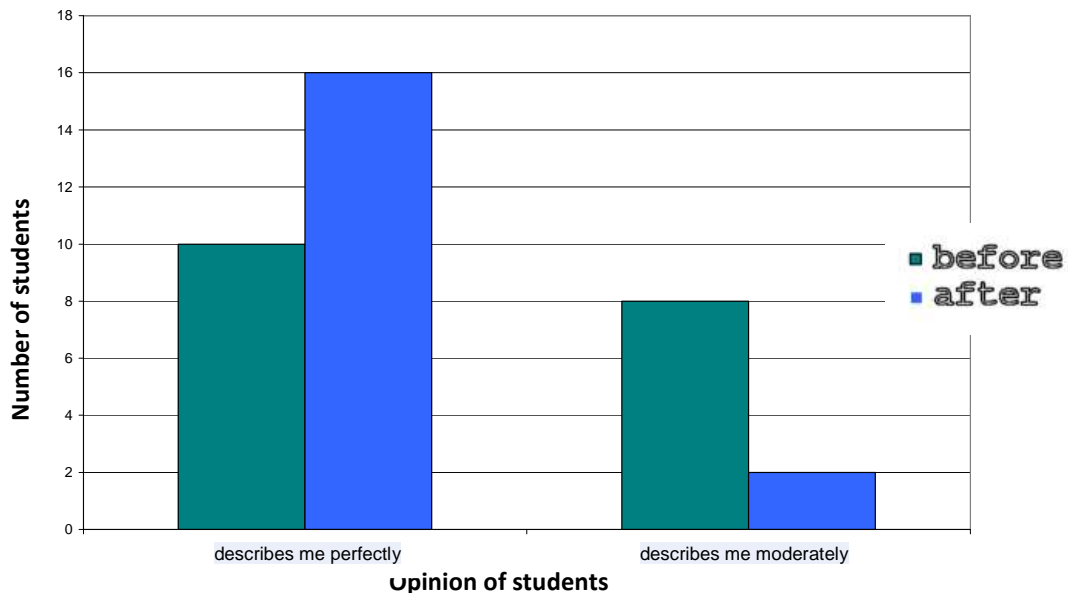


Fig.16. Trends presented by students related to discussion with colleagues at science lessons.