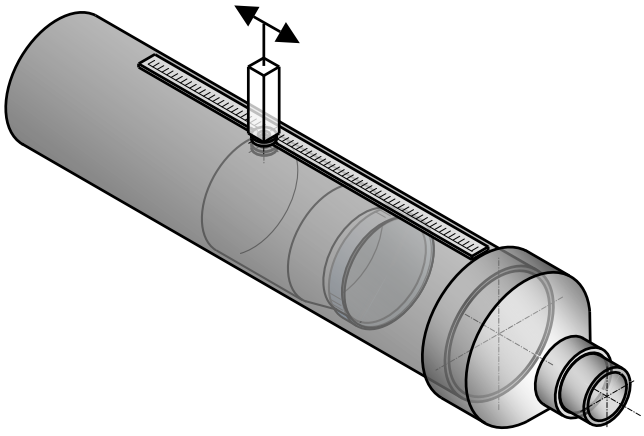
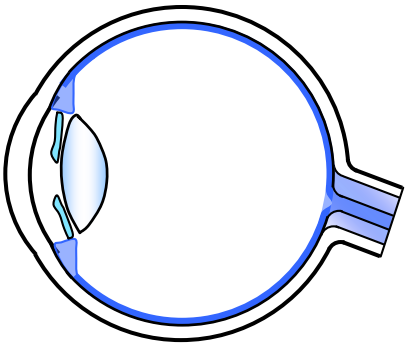
centre de développement pédagogique
pour la formation générale en science et technologie

Working document

"OPTICS AND VISION" TEACHING SEQUENCE

Guide for teaching and technical personnel





October 2014

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Notes:

- Linguistic review: October 2014
- In this document, the masculine is used to make the text more readable.

Introduction of the teaching sequence

This teaching sequence was developed to help understand the phenomena at issue when images are formed by a convergent lens. The subject is presented succinctly, since it will be dealt with at length in the secondary five physics class. The model of the eye presented in this guide will allow teachers for secondary three (ST or AST) to make the function of the eye and its crystalline lens more concrete. This sequence also allows the students to be confronted with the false notion that images are always formed in the focal point of the lens (focal point of the crystalline lens of the eye). It is spread over about four periods and prioritises the scientific investigation process.

The student's work is generally divided into three parts. To begin, we give the student an overview of various professions related to human vision. Then, the student discovers the formation of images by a lens through two scientific investigation processes and a directed laboratory. Finally, the student completes his exploration by various learning activities: finding the similarities between the model and the human eye, highlighting the limitations of the model and then exploring the formation of images by a lens in a more systematic manner, using drawing.

Overview of the teaching sequence

2nd cycle of secondary school (Secondary 3) ST or AST

Time required in class: 4 - 75 minute periods

Pedagogical intentions

- Understand the optical function of the human eye.
- Make it easier to understand the phenomena at issue when images are formed by a convergent lens.
- Confront the student with the false notion that images are always formed in the focal point of lenses (focal point of the crystalline lens of the eye.)
- Allow the student to acquire knowledge using the scientific investigation process.

Suggested context

The student experimentally discovers the general function of lenses and more specifically of convergent lenses. To do so, the student will have to study the function of the human eye using a model. We also propose that he explore professions related to the human eye.

Broad area of learning

Career Planning and Entrepreneurship
Focus of development: self-knowledge and awareness of his/her potential and how to fulfill it (recognition of his/her talents, strengths, interests and personal and career aspirations)

Targeted disciplinary competency:

- Seeks answers or solutions to scientific or technological problems (Scientific investigation process)
- Communicates in the languages used in science and technology

Statements from the *Progression of Learning*

Material World (E. Waves)

↻ e.i Locates different areas on the electromagnetic spectrum (e.g. radio waves, visible light, X-rays)

↻ f.i Describes how light rays are deviated by a plane reflective surface

✶ f.iii Describes how light rays are deviated when they pass through the surface of a convex or concave translucent substance

✶ g.i Determines the focal point of concave and convex lenses

✶ g.ii Describes the relationship between the focal point of a lens and the degree of deviation of light rays in different situations (e.g. accommodation of the crystalline lens, choice of corrective lenses)

Living Things: for ST (D. Systems) pour AST (C. Systems) → Relationships

↻ b.i - Explains the role of the peripheral nervous system (transportation of nerve impulses from the senses to the brain and from the brain to the muscles)

✶ c.i - Names the parts of the eye involved in vision (iris, cornea, crystalline lens, retina)
- Describes the function of the main parts of the eye

The Technological World (A. Graphical language)

✶ a.ii Associates the functional elements of a technical object with the appropriate diagram of principles (diagrams and symbols specific to lenses, path of light rays)

✶ h.ii Sketches simple objects freehand using different forms of representation (experimental data)

✶ j.iii Represents a simple shape in a cross-sectional view (cross-section of a lens or of the model)

Techniques (A. Technology)

✶ 1.c.i Chooses the best view of the technical object to describe a technical object *(model of the eye)*

Techniques (B. Science)

✶ d.vi Uses measuring instruments appropriately (e.g. ammeter, volumetric flask, *position of the image on the model*)

✶ e.i Uses observational instruments appropriately (e.g. magnifying glass, stereomicroscope, microscope, *model of the eye*)

Legend ✶ : Element worked on in the LES
↻ : Element studied previously
+: If desired

Evaluation of learning

The evaluation criteria as well as elements fostering understanding of the criteria related to the investigation process integrated into the student note booklet. You will find them framed at the bottom of the pages in question.

Suggested plan for the teaching sequence

Class (75 min.)		**Descriptions of each class**	**Documents**
Prerequisites		• Anatomy of the eye (dissection if possible) • Summary function of the eye	
Class 1	PREPARATION STAGE	**Background** • Presentation of the teaching sequence and some avenues regarding human vision professionals (optician, optometrist, etc.)	• Learning activities, p. 3
		Activation of previous knowledge • Building a network of concepts regarding the eye • Review in a full group discussion about the network of concept regarding the eye	• Learning activities, p. 4 • Theoretical capsule about geometrical optics, p. 4
	MANUFACTURING STAGE	**First step in the Scientific Investigation Process** • Discover the convergence and divergence of light rays using scientific investigation • Possibility of using the poster about the scientific investigative process to accompany the student during testing.	• "Scientific investigation about the convergence and divergence of light rays" notebook.
Class 2		**Second step in the Scientific Investigation Process** • Discover the formation of images using the model of the eye, using scientific investigation • Possibility of using the poster about the scientific investigative process to accompany the student during testing.	• "Scientific investigation about the formation of images using the model of the eye" notebook.
		Large group discussion • Discussion led by the teacher regarding convergent and divergent lenses	• Theoretical capsule about geometrical optics, p. 4
Class 3		**Directed laboratory** • Directed lab on the addition of glasses to the model of the eye	• Learning activities, p. 5
		Large group discussion • Discussion led by the teacher on combining lenses	• Theoretical capsule about geometrical optics, p. 5
	INTEGRATION STAGE	**Synthesis and integration activities** • Similarities between the human eye and the model • Limitations of the model of the eye	• Learning activities, pages 6 and 7
Class 4		**Synthesis and integration activities (continued)** • Locating images using a diagram • Review of the network of concepts from the preparation stage to consolidate learning • Short research about an anomaly or an illness of the human eye	• Theoretical capsule about geometrical optics, p. 6 • Learning activities, pages 8 to 10

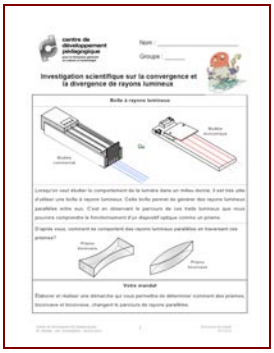
Documents related to the teaching sequence

Here are the documents related to this learning situation:

Learning activities (soundtrack for the sequence)

- This printable document accompanies the student throughout the suggested teaching sequence. Among other things, it contains the context, as well as several complementary documents related to the learning activities.
- An Adobe Acrobat (PDF) version is available on the CDP website[1].
- A Microsoft Word version (DOCX) is also available on request to adapt to the local reality or to a particular clientele.

Scientific investigation about the convergence and divergence of light rays



- This printable document makes up the notebook that accompanies the student throughout the scientific investigation process about the divergence of light rays.
- In it, the evaluation criteria are presented in frames at the bottom of the pages.
- A PDF version is available on the CDP website[1].
- A DOCX version is also available on request to adapt to the local reality or to a particular clientele.

Scientific investigation about the formation of images using the model of the eye

- This printable document makes up the notebook that accompanies the student throughout the scientific investigation process about the formation of images using the model of the eye.
- In it, the evaluation criteria are presented in frames at the bottom of the pages.
- A PDF version is available on the CDP website[1].

  A DOCX version is also available on request to adapt to the local reality or to a particular clientele.

Theoretical capsule about geometrical optics

- This document enables the teaching and technical personnel to accompany the students. It may even be a source of inspiration for the teacher during class preparation.
- A PDF version is available on the CDP website[1].

[1] The documents will be available in September 2015.

Fabrication stages of a homemade light beam box

- This document enables the practical work technicians to make a homemade light beam box using three linear module laser diodes. At a cost of about $8, it is relatively inexpensive. The document includes the nomenclature, as well as all the technical drawings required for the fabrication of the box.
- A PDF version is available on the CDP website[2].

Technical file for the model of the eye

- This document enables the practical work technicians to make the model of the eye. This file contains all the technical drawings and ranges required.
- Since the fabrication of this model is relatively simple, it may be built by the students. Depending on the distribution of the work among team members and the students' abilities, one or two periods will need to be allotted to this task.
- A PDF version is available on the CDP website[2].

Video presentation of the model of the eye

- This video presents the function of the eye very simply. It also demonstrates that the image is formed upside down on the retina of the eye.
- It is available at the following address (in French): https://www.youtube.com/watch?v=NwkvbmFtlME

Animation guide for the teaching sequence

The next pages of this guide are related to the teaching plan suggested on page 5. There are suggestions for animation, as well as examples of solutions. The materials preparation for the labs is also broached.

Glossary

Crystalline lens, Cornea, Pupil, Iris, Vitreous humour, Sclerotic, Accommodation of the crystalline lens, Corrective lenses, Glasses, Eyewear, Contact lenses, Anomaly, Illness, Optician, Optometrist, Ophthalmologist, Myopia, Hypermetropia, Astigmatism, Presbyopia, Cataracts, Glaucoma, Geometrical optics, Light ray, Light, Electromagnetic spectrum, Reflection, Refraction, Model, Investigation, Convergent lens, Divergent lens, Concave lens, Convex lens, Focal point, Focal length, Top of a lens, Transparent substance, Translucent substance

[2] The documents will be available in September 2015.

Background

Oriented school
The following videos could support your presentation regarding professions related to human vision.

⇒Training as an **optician**? (Collège Édouard-Montpetit) (In French)
https://www.youtube.com/watch?v=DbugpOaLTWA [duration 3:01]

⇒Technique d'orthèses visuelles **optician** (Collège François-Xavier-Garneau) (In French)
https://www.youtube.com/watch?v=GjPp8HmwrR0 [duration 2:25]

⇒Vision exam performed by an **optometrist**, specifically for diabetic patients (In French)
https://www.youtube.com/watch?v=1nz20VkelBI [duration 4:49]

⇒Vision exam performed by an **optometrist**, specifically for grade school students (In French)
https://www.youtube.com/watch?v=PaSSnkCsjwQ [duration 3:18]

⇒Laser correction of myopia, performed by an **ophthalmologist** (In French)
http://www.youtube.com/watch?v=UY94toajiC8 [duration 4:56]

⇒Cataract surgery performed by an **ophthalmologist** (In French)
http://www.youtube.com/watch?v=8cwacDFDgB8 [duration 2:43]

Activation of previous knowledge

Building a network of concepts enables the students to refresh their memory. The student could in fact have broached certain concepts related to the eyes in grade school or in the first cycle of secondary school. In addition, the anatomy of the eye, as well as an overview of its function should have been presented to the students previously in class.
First, you may let the students outline a network of concepts as a part of a team. Then in a large group discussion, you can combine everyone's ideas on the board.

Here are some words that could be a part of the network of concepts:

Crystalline lens, Cornea, Retina, Cones, Macula, Rods, Optical nerve, Blind spot, Pupil, Iris, Aqueous humour, Vitreous humour, Ray, Light, Spectrum, Colour, Convex lens, Concave lens, Refraction

This activity could be an opportunity for the teacher to become aware of students' erroneous concepts. By better understanding these initial notions, it will be easier to accompany the students in the activities.
It is also important to come back to this network of concepts at the end of the teaching sequence, during the integration phase. This review is an important step in the metacognitive process.

First step in the Scientific Investigation Process

Suggested scientific investigation process

The scientific investigation process[3] we propose is first and foremost a problem resolution or discovery process. This is the reason we give the student a notebook, rather than a booklet reproducing a complete laboratory report. This approach allows the process to come closer to what actually happens daily in research laboratories. It also brings a little spontaneity and passion to the experimental process.

Pedagogical intentions (investigation about the convergence and divergence of light rays)

- Enable the student to discover how light rays are deviated when they go through the surface of a convex or concave translucent substance (convergence and divergence of light rays)
- Enable the student to visualise the position of a focal point
- Enable the student to better understand the optical function of the human eye

Notes for animation	Documents
• Light ray boxes and prisms are normally used in physics classes in secondary five. It is surely possible to borrow them. If it is not possible, you can make a homemade light ray box using the fabrication document (on page 7 of the present document). You will need to plan a few minutes to explain the operation of the light ray boxes to the students.	• "Scientific investigation about the convergence and divergence of light rays" notebook, p. 1
• The student must not touch the equipment before formulating his hypothesis. • The formulation of the hypothesis may be presented more or less formally, since the aim is informative. • The teacher could feed the thought process during the formulation of the hypothesis by invoking: the use of a magnifying glass, how we see the eyes through glasses (bigger, smaller), the image of a fish in a fishbowl, a crystal ball, etc.	• "Scientific investigation about the convergence and divergence of light rays" notebook, p. 2
• The student traces may be recorded as a drawing or in written form. • When the student notebook is printed, printing pages 3 and 4 side by side will make it easier for the students to work.	• "Scientific investigation about the convergence and divergence of light rays" notebook, pages 3 and 4

What to take away from this process

- A convex prism makes parallel rays converge at a focal point.
- A concave prism makes parallel rays diverge.

Evaluation

The evaluation criteria as well as elements fostering understanding of the criteria are presented in the framed sections. The greyed out elements cannot be evaluated.

[3] The poster for this process is available on the CDP website at the following address: http://www2.cslaval.qc.ca/cdp/UserFiles/File/downloads/affiches_sec/invest_ang_sec_8x11.pdf

Second step in the scientific investigation process

Suggested scientific investigation process

The scientific investigation process[4] we propose is first and foremost a problem resolution or discovery process. This is the reason we give the student a notebook, rather than a booklet reproducing a complete laboratory report. This approach allows the process to come closer to what actually happens daily in research laboratories. It also brings a little spontaneity and passion to the experimental process.

Pedagogical intentions (investigation about the formation of images using the model)

- Enable the student to visualise the position of the focal point by observing an "infinitely" distant object (e.g. a faraway car or tree)
- Confront the students with the false notion that images are always formed at the focal point of convergent lenses (focal point of the crystalline lens for the eye) otherwise, the student could believe this false notion until his secondary five physics class.
- Enable the student to better understand the optical function of the human eye

Notes for animation	Documents
• A complete technical file to make the model of the eye (see page 7 of the present document). • The lens of the model of the eye, which serves as a "crystalline lens" has a focal length of 10 cm.	• "Scientific investigation about the formation of images using the model of the eye" notebook, p.1
• The student must not touch the equipment before formulating his hypothesis. • The formulation of the hypothesis may be presented more or less formally, since the aim is informative. It should nonetheless include a justification. • The hypothesis could deal with the inversion of the direction of the image relative to the object.	• "Scientific investigation about the formation of images using the model of the eye" notebook, p.2
• The student traces may be recorded as a drawing or in written form. • The student may wish to use a draft version to note his data to begin with. In the end, though, the use of a formal table is desirable and even to their advantage.	• "Scientific investigation about the formation of images using the model of the eye" notebook, pages 3 to 5

What to take away from this process

- The direction of the image formed is upside down relative to the object.
- Images are not always formed at the focal point of the lens. In fact, the closer the object, the further the image is from the focal point.
- If an object is far away, the image is formed almost at the focal point (in our case, 10 cm. from the lens).

Evaluation

The evaluation criteria as well as elements fostering understanding of the criteria are presented in the framed sections. The greyed out elements cannot be evaluated.

[4] The poster for this process is available on the CDP website at the following address: http://www2.cslaval.qc.ca/cdp/UserFiles/File/downloads/affiches_sec/invest_ang_sec_8x11.pdf

Large group discussion

- See the "Theoretical capsule about geometrical optics" document on page 4
- A convergent (convex) lens makes parallel rays converge at one (focal) point.
- A divergent lens (concave) makes the rays diverge.
- The image formed by a convergent lens is upside down.
- Only a distant object forms an image at the focal point.
- The following links are of interest:
  http://www.youtube.com/watch?v=G303o8pJzls&feature=em-share_video_user
  http://ekladata.com/nW5sWMyodLC5KTE7BzxP2qVaodA/lentille_convergente.swf (In French)

Directed laboratory

Directed lab on the addition of glasses to the model of the eye

A learning activity is called a "Directed laboratory" when the activity replicates a process, an existing protocol, etc. In our activity, the materials are supplied to the students and the manipulations are very similar to the previous activity. The observations made by the students are also very similar.

Pedagogical intentions

- Allow the students to visualise the effect on the formation of images of adding a convergent or divergent lens (glasses).
- Enable the student to better understand the optical function of the human eye

Notes for animation	Documents
• **The student must always use a distant object** (as far as possible) during this directed laboratory - a landscape, for instance. • Here are the suggested lenses for the model: · Main lens: convergent, focal length of 10 cm. · Convergent corrective lens: focal length of 15 cm. · Divergent corrective lens: focal length of -20cm or -15 cm.	• Learning activities, p. 5

What to take away from this process

- Without glasses, the image forms at 10 cm from the main lens, since its focal length is 10 cm.
- The addition of a convergent lens brings the image of an object closer to the main lens (in our case, the image will form at a distance of less than 10 cm). In the case of the eye, a convergent lens is used to correct the anomaly of hypermetropia.
- The addition of a divergent lens distances the image of an object from the main lens (in our case, the image will form at a distance of more than 10 cm). In the case of the eye, a divergent lens is used to correct the anomaly of myopia.

Evaluation

Only the criteria "Proficiency of subject-specific knowledge targeted in the Progression of Learning" appears at the bottom of the page.

Large group discussion

- See the "Theoretical capsule about geometrical optics" document on page 5
- The addition of a convergent (convex) lens makes the rays converge more quickly. The image forms closer to the main lens.
- The addition of a divergent (concave) lens makes the rays converge more slowly. The image forms further from the main lens.

Synthesis and integration activities

Similarities between the human eye and the model of the eye

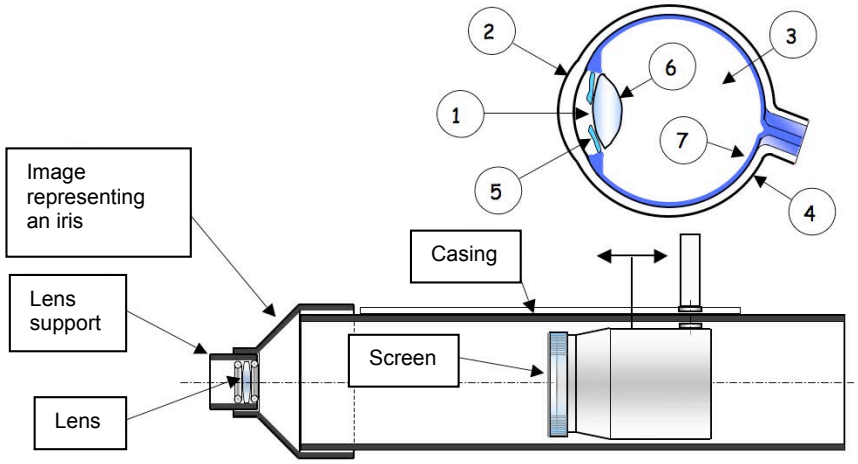
In this activity, the student discovers the similarities between the human eye and the model of the eye. This exercise makes the function of the eye more concrete. The model allows the student to visualise what would otherwise be invisible.

Pedagogical intention

- Allows the student to associate the structures of the eye to the components of the model in order to better understand the optical function of the human eye

Notes for animation	Documents
• This exercise is a review of the anatomy of the eye, since the student has to identify its various structures. • A model of the eye could be made available in class.	• Learning activities, p. 6

Evaluation
Only the criteria "Proficiency of subject-specific knowledge targeted in the Progression of Learning" appears at the bottom of the page.



Complete the following table using the diagrams above

Identification number	Name of the corresponding structure in the human eye[5]	Name of the corresponding component in the model of the eye (if possible)
1	***Pupil***	***Hole made by the lens support***
2	***Cornea***	***(The cornea may also be associated to the lens, since it also makes the light rays converge. It is the cornea that is shaped when myopia is corrected using laser surgery.)***
3	*Vitreous humour*	*(The air trapped between the lens and the screen may be associated to the vitreous humour).*
4	*Sclerotic*	*Casing*
5	***Iris***	***(The image of the iris is presented on the model, but it does not play the role of the diaphragm!)***
6	***Crystalline lens***	***Lens***
7	***Retina***	***Screen***

[5] The structures of the eye not in bold are not mentioned in the progression of learning.

Limitations of the model of the eye

During this activity, the student specifies the limitations of the model, explaining the reasons that make this model imperfect. It can highlight the operations carried out by the human eye that cannot be reproduced by the model.

Pedagogical intention

- Enable the student to understand that a model is a simplified representation of reality that helps to explain a phenomenon, for example the formation of images by the eye
- Allows the student to explain the functional limitations relative to the human eye.

Notes for animation	Documents
• A model of the eye could be made available in class. • The student could think up ways to make the model more effective and talk about it in the full group discussion.	• Learning activities, p. 7

Evaluation

Only the criteria "Proficiency of subject-specific knowledge targeted in the Progression of Learning" appears at the bottom of the page.

Structure of the human eye	Corresponding component in the model	Explanation of the reasons the model is limited and imperfect
The Iris — pupil assembly	*Lens support and image of an iris*	*The lens support only allows the replacement of the main lens and the superimposition of several lenses. The image of the iris is only aesthetic.* ***The iris - pupil assembly of an eye allows the amount of light reaching the retina to be modulated. It is a diaphragm whose diameter adjusts automatically in order to optimise the amount of light that enters the eye. The model does not control the amount of incoming light.***
Crystalline lens	*Lens*	*The model's lens has a fixed focal distance of 10 cm. It may also be said that the focal point of the lens is at a distance of 10 cm. The model adjusts to objects placed at different distances by modifying the lens - screen distance.* ***Contrary to the lens of the model, the crystalline lens does not have a fixed focal length. Its focal point may be moved, since the crystalline lens has variable curvature. The eye adjusts to objects placed at different distances by modifying the convexity of the crystalline lens.*** *Optional: The cornea of the eye acts as a fixed lens. It participates substantially in the convergence of the light rays in conjunction with the crystalline lens.*
Retina	*Screen*	*The screen of the model is aptly named. In its case, it simply enables animated images to be projected. The screen's translation gives the model the adjustment necessary for projecting clear images.* ***The retina is much more than a simple projection screen. It is layered with sensors (cones and rods) that detect light and transform it into nerve signals.*** *Optional: The brain then takes care of interpreting these nerve signals in particular by putting the images right side up.*

Locating images using a diagram

Pedagogical intentions

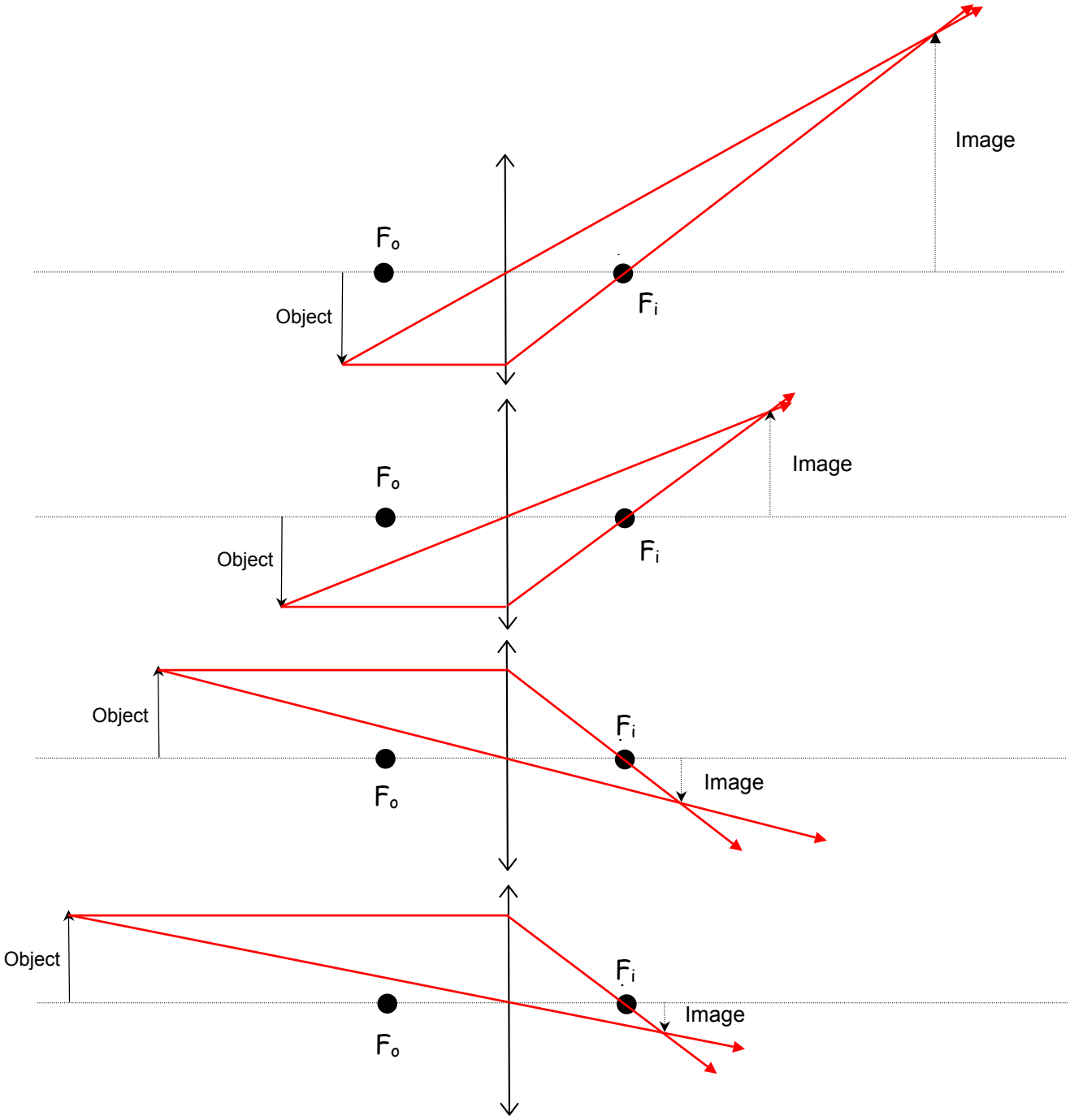
- Enable the student to better understand the optical function of the human eye
- Confront the student with the false notion that images are always formed in the focal point of lenses (focal point of the crystalline lens of the eye.)
- Validate what the student has learned during the teaching sequence (where images form, the direction of the formed images, the effects of a convergent lens, etc.)

Notes for animation	Documents
• The theoretical capsule explains how to locate the images, simply. • The teacher must take a few minutes to show the student how to: · Diagram a lens, the main axis, the object (arrow) and the image. · Trace two rays required for locating the real image. The example in the theoretical capsule may be repeated with the student. The following animations are of great interest: · http://www.proftnj.com/opt-lentimage.htm (In French) · http://www.sciences.univ-nantes.fr/sites/genevieve_tulloue/optiqueGeo/lentilles/lentille_mince.html (In French) • You must tell the student that only the focal point of the image is useful for the time being. The focal point of the object will be used in the study of the divergent lens in the secondary five physics class. • When the student notebook is printed, printing pages 8 and 9 side by side will make it easier for the students to work. • Locating images from divergent lenses **is not** addressed. • The distinction between a virtual image and a real image **is not** addressed. • The height of images of objects **is not** addressed quantitatively.	• Theoretical capsule about geometrical optics, p. 6 • Learning activities, p. 8 • The corrected version is on the next page.

What to take away from this process

- The direction of the image formed is upside down relative to the object.
- Images are not always formed at the focal point of the lens.
- The image of a close object forms beyond the focal point.
- The further the object, the closer the image is from the focal point.
- The image always forms where the rays converge.
- The image of a distant object forms at the focal point.

Fill in the following drawings by tracing two rays from the point of the arrow representing the object.



Animation suggestion after the exercise (Learning activity, p. 9)

On the drawings from the previous page, in which direction do the formed images appear? Is this consistent with your observations of the model?
The images appear upside down relative to the object. Yes, the observations made with the model of the eye always showed the images upside down.

Carefully observe the progression in the four images drawn on the previous page. At which position would an image placed to the left at a very great "infinite" distance, appear?
In this case, the image would form very close to the focal point.

In everyday life, what size does a very distant object appear to us? Is this consistent with the drawings on the previous page?
A very distant object seems very small. Yes, the further the objects are, the smaller the images are.

When you look at the sky on a starry night, how big do the stars seem? How do we perceive them?
The stars seem very small, like little dots. We perceive them as being very far away.

Review of the network of concepts from the preparation stage

It is critical to review the network of concepts from the preparation stage so as to consolidate what has been learned. This review is an important step in the metacognitive process.

Anomalies or illnesses of the human eye (enrichment)

Suggested complementary resources
Introductory videos: http://santevisuelle.com/v1/ (In French)

Anomalies	Illnesses
• Myopia	• Cataracts
• Hypermetropia	• Glaucoma
• Astigmatism	• Macular degeneration
• Presbyopia	• Retinal detachment

Excellent simulator for myopia, hypermetropia and presbyopia and the possible corrections. (In French)
http://www.sciences.univ-nantes.fr/sites/genevieve_tulloue/optiqueGeo/instruments/correction.html

Video about astigmatism (In French)
http://www.youtube.com/watch?v=el6PBuxDa4g

Video about cataracts (In French)
http://www.youtube.com/watch?v=9UhhCHfx1O8

Video about glaucoma (In French)
http://www.youtube.com/watch?v=B2bcHIQUsgo

Video about macular degeneration (In French)
https://www.youtube.com/watch?v=Ft6RScko_Tg

Video about retinal detachment (In French)
http://www.youtube.com/watch?v=my2IP9RAJy4