Teaching and learning in geometrical optics in Burkina Faso third form classes: Presentation and analysis of class observations data and students' performance

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Abstract

Based on 7.55% and 16.14% percentage of success in optics of Burkina Faso third form students' review year-end 2009 and 2010, respectively, this paper investigated the reasons of students' poor performance in geometrical optics in Burkina Faso third form classes through the following question: why students after optics classes were not able to determine the position and the height of images given by converging lens or loupe when they knew object position and height? For our investigation we observed and analysed ten (10) lessons of two (2) teachers' lessons and after evaluation, analysed hundred and sixty five (165) students' productions of five (05) secondary schools in Koudougou city. In class, we found that student' difficulties in learning condition are coming from teacher methodologies. Two hypotheses were set and guide our research: (1) *Students' difficulties are due to their misconceptions of light ray and its utilization* and *(2) Students' difficulties are due to bad teaching*. The present study highlighted that *t*eachers used inappropriate light rays during imagery and produced non clear schemas for students. This class conditions did not permit to students to build their knowledge. The analysis of students' productions showed that they were uncomfortable (24.02% of success) with optics concepts (confusion between real light ray and virtual light ray; ignored the meaning of emergent ray) and used bad procedures during imagery (only one light ray is used for this action). For improving student learning, in class, teachers might clearly identify the three (03) useful light rays and proposed clearly schema which showed the utilization of the chosen light rays. They will correctly define the main used concepts and show how to use them through clearly schema.

Keywords : Geometrical optics, real and virtual light rays, emergent light ray, difficulties

1. Introduction

Many papers treated student learning problems in physical sciences (e.g. Reif, 1983; Viennot, 1989; Maarouf and Kouhila, 2001; Ouattara, 2005; Koffi, 2010; Oké, 2010 ; Oldache and Khiari, 2010). The investigation of student leaning difficulties in physics in Burkina Faso has been the subject of many studies. These previous studies concern mechanics, electricity and the problem of transition between secondary school and university (Ivo and Ouattara, 2008; Koné and Ouattara, 2009; Somé and Ouattara, 2009, Pitroipa and Ouattara, 2008). Here we will interest to the difficulty of students in geometrical optics in third form. The optical devices (cameras, loupes, lenses, mirrors, etc.) are commonly used today but understanding of their system of work by students is not easy in class. Several papers concerned students' difficulty in optics (e.g. Galili, 1996; Gallili and Hazan, 2000; Kaminski and Mistrioti, 2000; La Rosa, et al., 1984 ; Maurines, 2000;

2001; Ouattara and Boudaoné, 2012; Palacios et al., 1989; Romdhane, 2008 and Viennot, 2000). In Burkina Faso secondary school learners study lens and loupe in third form. By examining their copies in optics during the exam of BEPC (first cycle brevet) for the two sessions of years 2009 and 2010 it had been shown that 92.45% and 83.86% of students do not succeed, respectively (Boudaoné, 2012; Ouattara and Boudaoné, 2012). These results raise our research question: Why students do not succeed in geometrical optics after teaching?

To investigate students' poor performance and to propose useful solutions in order to overcome their difficulties, in this paper, firstly, we will analyse learning conditions during optics class (teachers' methodologies and students' works will help us). Our class investigation objective is to see and point out relationships between students' difficulties and teachers' procedures in class. Secondly we will examine hundred and sixty five (165) learners' productions after evaluation. An eventual link will be made between students' performance and learning conditions.

It is important to note that student' conceptions are responsible to their difficulties (Courtillot and Ruffenach, 2006). The well understanding of optics concepts depends on the perception of light (Physics), eye functioning (Biology) and perception interpretation (Psychology) (Feynman et al. 1964, Gregory, 1979 and Galili and Hazan, 2000).

Perales Palacios et al. (1989) worked is based on the relationship between students' conception and pedagogic variables. They found that 71% of learners did not distinguish light ray and light beam. If this confusion exists, it will be impossible for learners to success during imagery in class context. Our work did not focus this distinction because it will only concern the use of light ray for image determination. This confusion may be exist and probably influences the relationship between student and optics system during imagery. Unfortunately for the lack of laboratories carrying out that confusion is out of the scope of the present study.

Viennot (1996) pointed out the difficulty of first year university students with the materialization of light ray. In fact, first year students are invited for the first time to materialize two light rays issued from the same point by using converging lens. For the second time to materialize a third light ray always issued from the same point by using the same converging lens. These students are able to materialize the first two light rays and are not capable to success for the third light ray. This result shows that students do not understand the basic principle of image formation. This basic principle can be expressed as: any light ray issued from an object point and passing through a converging lens converges towards an image point. Based on this principle students by materializing the two first light rays issued from the same object point have automatically got the image point for the two first incident light rays are converged towards the same image point after passing through the converging lens. Therefore it becomes evident that the third light ray must converge towards the same image point when it is coming from the same object point.

Viennot (1996) work underlines that students difficulty with imagery problem persists after secondary school. Our investigation is different from that of Viennot (1966). In fact, firstly the sample composition is different (age; experimental experience; social context) ; secondly our students are invited only to materialize two light rays by using converging lens and thirdly we will used not only converging lens but also loupe.

Basically in didactic of physics, with constructivist point of view, the interpretation of students' conception is mainly due by pointing out their conception expressions (Noupet, 2004; Ouattara, 2005; Ivo and Ouattara, 2008; Koné and Ouattara, 2009; Pitroipa and Ouattara, 2008; Somé and Ouattara, 2009; Boudané, 2012), in psychology their conception arrangements (Galili, 1995; Galili and Kaplan, 1996; Galili and Lavrik, 1998) and in epistemology their conception origins (Bachelard, 1980). The above learning interpretations highlight two types of approach : micro approach bases on cognitive understanding (Gilbert et al., 1982; Osborne, 1996; Solomon, 1994; Smith et al., 1993; Tobin et al.,1994) and macro approach lies on the description of the products of learning (Gali li and Hazan, 2000). In the case of imagery it has been exhibited that students have "moving image" conception and "statistic light and its instantaneous expansion" conception (Ronchi, 1970; Lindberg,1976; Park, 1977). The latter has been explicitly expressed in term of schemes (Galili, 1995; Galili and Kaplan, 1996; Galili and Lavrik, 1998; Galili and Hazan, 2000). It can be retained from these researches that for students image pre-exits and travels. That thinking must block them during the construction of their knowledge in class. In Burkina Faso several secondary schools do not experiment in optics because they do not have laboratories or if it does exist, laboratories do not have appropriated tools for optics experimentation. Therefore, class imagery is made theoretically and we cannot observe the versatility of students' knowledge about image noted by several authors (Goldberg et al., 1991; Bendall et al., 1993).

The context of teaching and learning optics in Burkina Faso can be expressed as: (1) geometrical optics is taught in secondary school (fourth, third and scientific first forms) and in university (first and third years); (2) several high schools and universities teachers complain of students' poor performance in geometrical optics. To improve student's performance in optics, it is important to think about their learning conditions specifically during the beginning classes. As students learn for the first time geometrical constructions in the third form of secondary schools, students and teachers of this form will constitute our sample. Moreover, the third form is an exam class. Therefore, improving students learning conditions increases their chances of success in the review year-end.

2. Learning and teaching context

Most of secondary schools in Burkina Faso does not have laboratory for physical sciences experimentations. Physics and chemistry teaching focus four objectives: (1) method objective for permitting scientific methods acquirement, (2) attitude objective for developing creativity and criticize spirit, (3) knowledge objective for giving basic concepts and (4) expertise objective for permitting specific experimentation aptitudes acquirement. Furthermore, official documents precise that physics and chemistry teaching objectives must be an initiation to experimental sciences. Geometrical optics has been introduced since scholar year 1992-1993. But for different reasons geometrical optics program has been evaluated in the year 1996. Six chapters (light analysis and synthesis, converging lenses, imagery, geometrical constructions, loupes and mirrors) constitute this part of physics program. It is important to note that only the last five chapters are concerning by geometrical constructions. Therefore, we only focus our attention to lenses and loupes because converging lenses and loupes are devoted to the theoretical study of theses optics systems. The other chapters consist of their applications.

3.Materials and Methods

3.1 Sample

Hundred and fifty six (156) students of four (4) public and private secondary schools and two (2) experienced teachers (6 mean years old of teaching) taken from private and public schools constitute our sample.

Our study area is the Centre-West Regional Direction of the Ministry of Secondary Schools and Higher Educations located in Koudougou city. The four secondary schools and student numbers enlist are: (a) *Public school*: Lycée provinciale de Koudougou (58 students) and Lycée municipale de Koudougou (31 students) and (b) *private schools:* Lycée privé Alpha Sanoussa de Koudougou (52 students) and Lycée Privé le Germinal de Koudougou (24 students). In our sample, the biggest public school is Lycée provinciale de Koudougou and that of private school is Lycée privé Alpha Sanoussa de Koudougou. The students sample shows fairly 50% students for each type of school and more than two- thirds of students for the biggest schools.

Teachers involved are coming from Lycée municipale de Koudougou and Lycée Privé le Germinal de Koudougou according to their teaching experience and principally for their availability.

3.2 Instruments of assessment

In the present study two instruments have been used: class observations (six lessons for one teacher and four for the other one) followed with focus interviews and students' productions (165 evaluation copies).

For class observation data acquiring observation grid has been used. This grid comprises 5 parts addressing sequential steps, class animation, lesson content, didactic auxiliaries (chalk, materials, etc.) and pedagogic methods and techniques. It is important to note that our grid is conformed to Burkina Faso official observation grid. The data carried out here will be used for qualitative analysis.

Our evaluation subject comprises 4 exercises divided into 2 parts: the first part concerns declarative knowledge and the second part procedural knowledge (see annexe) emphasis with our research hypothesis. The test duration is 2 hours and students have been evaluated during academic year 2010-2011. Productions results are used in the present study for quantitative analysis.

3.3 Research hypotheses

Two specific hypotheses were set and guide our data analysis:

1. *Students' difficulties are due to their misconceptions of light ray and its utilization.*

The indicators of this hypothesis are given in table 1

Table 1: Main assessment items

Questions	Items objectives	Code
1.	Knowledge of light ray (definition, characteristics and utilities)	**E1**
2.	Definition of emergent light ray	**E2**
3.	Image definition by using light rays	**E3**
4.	Knowledge of the necessary minimum number of light rays for imagery	**E4**
5.	Representation of light ray that does not model the real light propagation	**E5**
6.	Image construction by using converging lens and two specific light rays when knowing extended object height and position	**E6**
7.	Image construction by using loupe and two specific light rays when knowing extended object height and position	**E7**
8.	Object construction by using converging lens and two specific light rays when knowing image height and position	**E8**

During the present study we decided to apply 75% confidence level. Therefore this hypothesis is rejected if 75% of students succeed to 75% of the all items involved.

2. *Students' difficulties are due to bad teaching*

The indicators emerged from lesson analysis grid. The main criteria are: (1) The used of only one light ray passing by the centre during imagery; (2) Utilization of light passing by the lens summits; (3) bad materialization of virtual light ray; (4) bad contextualization of mathematics concepts in physics; (5) Production of hazardous figures.

By applying 75% confidence level, we obtain the following condition: This hypothesis is rejected if 75% of the main indicators are false.

4. Results and discussion

4.1 Class observations data: presentation and analysis

4.1.1 Imagery with converging lens

This part concerns an exercise of imagery in class context after teaching. Teacher invited learners to construct an image A'B' by using converging lens. Figure 1 shows in panel a student constructing an image A'B' and in panel b teacher's solution. It appears that the image A'B' obtained by the lady (panel a) is not the real image because her solution is not true. In fact, the analysis of this panel points out that the student used only one light ray issued from the object A and also coming from the object B. She forgot that at least two light rays are necessary to construct an image. The panel a analysis also shows that student used the property of central symmetry or axial symmetry to get the image A'B'. Student did not pay attention that this property must be applied when (1) both image and object spaces have the same refraction indices and (2) the object is in the principal axis. Basically, it is worked for lens centre and its foci. It must be noted here that in secondary school the refraction indices of both image and object spaces are the same and considered as that of the vacuum because air refraction indice is assimilated to one for easy calculation. Therefore only the nature of the object must be considered. It is well known that interdisciplinary mathematics and physics is strongly encouraged for improving student knowledge acquiring in Physics but here we note the bad contextualisation of mathematics method in physics. We called this mistake "interdisciplinary mistake" or "bad contextualisation". Usually literatures reported that students do not used their mathematics knowledge in other contexts (e.g. Ouattara, 2005; Some et Ouattara, 2009). The present result is due to the absence of physics laboratories. In fact, in laboratory, it will be possible to establish for example the positions of the foci by using their definitions.

Panel b (this figure is taken from student notebook) shows teacher's solution during lesson class for the same kind of exercise. It is evident that student reproduced here what she learned a days before. The examination of figure 1b shows the following property: object and image are in the same line passing by lens centre. Therefore image can be seen everywhere when screen crosses light ray. It is the typical expression of "moving image" conception (Halili and Hazan, 2000). This observation points out that students' poor performance is due to bad teaching.

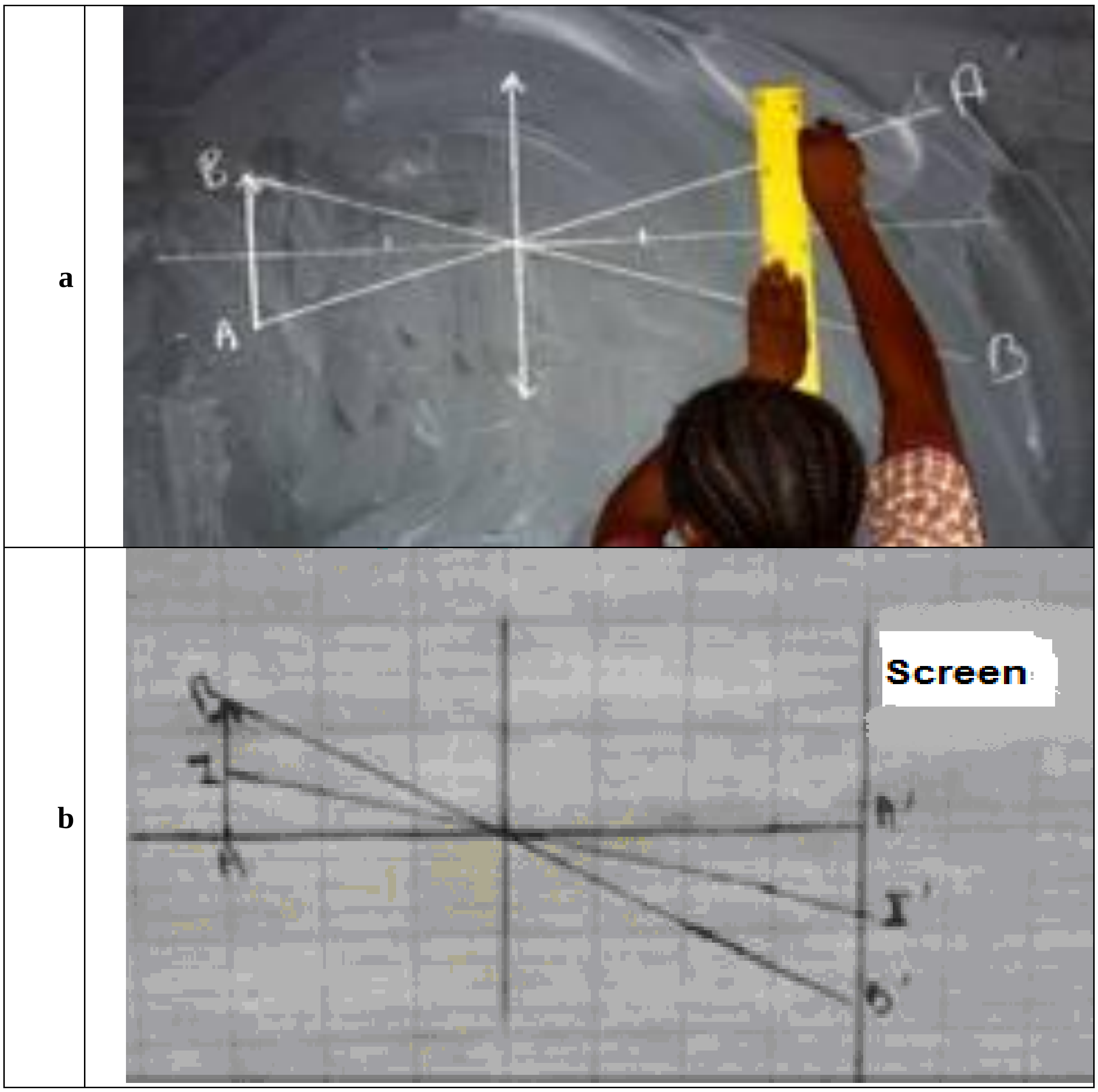


Figure 1: Determination of image position by using converging lens in class context

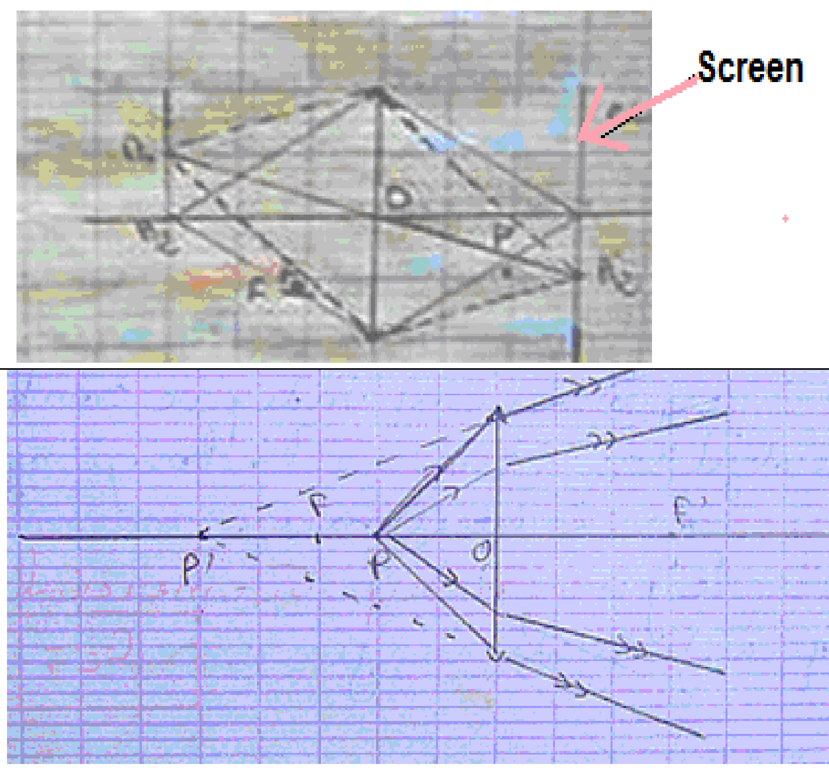
All figure 2 panels are taken from students' notebook and concern constructions obtained during optics class. Figure 2a shows that only real image can be observed in screen. These are the main steps of this imagery: (1) Positioning of screen; (2) Materialisation of the two light rays issued from A_1 and A_2 and passing by lens centre; (3) Determination of images A_1' and A_2'. These points are the intersections of the screen and the two light rays issued from A_1 and A_2, respectively. (4) Materialisation of the other light rays with respect of object point issued. This teacher's approach gives unclear schema that is not usable for students. This teacher pedagogy confirms what students believe: the subject of optics is obscure and difficult and teachers' help often insufficient (Galilli and Hazan, 2000).

Figure 2b is the materialization of teacher's hazardous method. Panel b shows the construction of the image P' of an object P located between focus object and lens centre. As P' is virtual image dotted lines are used to materialize virtual light rays. It can be noted a use of non appropriate light rays for getting P'. Therefore, how students can correctly reproduce this figure if there is any rule? It can be retained that this panel describes the principle of loupe.

Figure 2c shows the utilization of the three specific light rays for getting image: (1) light ray issued from focus object, (2) light ray passing by lens centre and (3) light rays passing by focus image. For getting image, at least two specific light rays are necessary (any two of the three specific light rays previously enumerated). Here, teacher used the rays passing by both foci for obtaining A' and B' and light ray passing by the centre for getting P'. This figure is unusable for it is confused. Basically, it will be useful to make three separate figures for each type of light ray and put different arrows in each ray for showing the direction of light propagation. Each light ray must be made by using different colours of chalk. After that if teacher thinks necessary to put them together, he can do that with respect of chalk colours used before.

a

b



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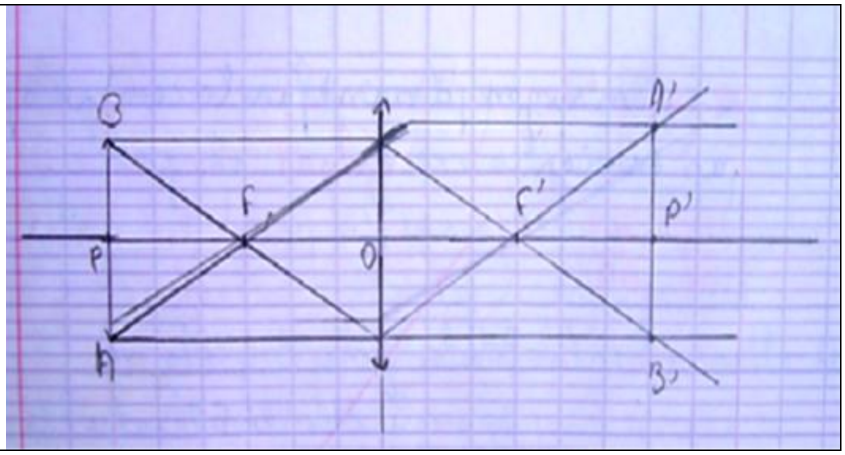

Figure 2: Imagery in class context

4.1.2 Imagery with loupe

Figure 3 gives two different methods to construct image in class context. This figure shows an unworkable hazardous construction. In fact, only one specific light ray is used and there is no foci location. Teacher obtained image A' by utilizing a wrong light ray even though two light rays must be used in that case. For getting B' only one light ray (materialized by the line issued from B and passing by the centre) and probably the intersection of that light ray and the line issued from A' and perpendicular to optical axis. One question can be asked: why teacher used dotted line to materialize virtual image without giving the foci positions (these foci positions must indicate an object located between focus object and optic centre)? Surely, after this class context student will have many difficulties in geometrical optics.

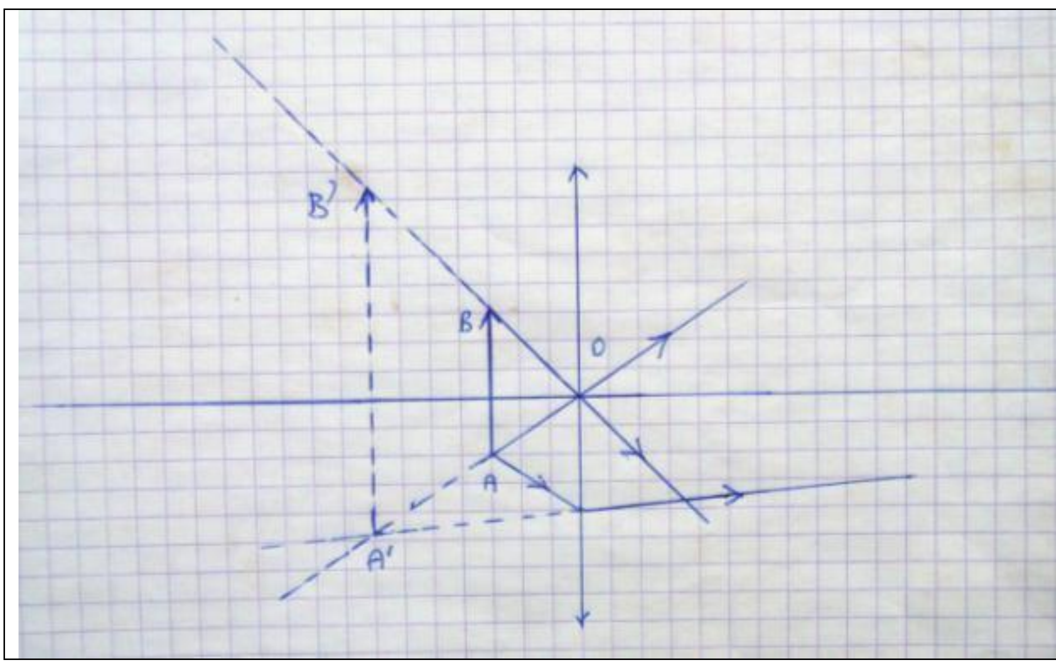

Figure 3: Image construction by using loupe in class context

4.2 Students' productions: presentation and analysis

Table 2 gives students' mark intervals. One can see that only 9.70 % (16/165) got the mean (10/20) and 60% of marks are inferior to 5/20. These results express the difficulties of students after optics class.

Table 2: Students' global performance

Intervals	[0 ; 5 [	[5 ; 10 [	[10 ; 15[	[15 ; 20]	Total
Number of students	99	50	**15**	**1**	165
Global Percentage (%)	60.00	30.30	9.09	0.61	100
Success percentage (%)			**9.70**		

Mark histograms shown in figure 4 highlight that the global percentage decreases as an negative exponential function. This function is expressed as: $Y = 4.2827 \times \exp(-0.9X)$ with y the global percentage of marks and X each interval median mark. This function must be used as a tool of students' mark estimation after optics class. The different coefficients of the above function are determined by using least squares method. The significance of the X coefficient is obtained by using Fisher's F criterion given by pollard (1977): $F = (n-2)\frac{r^2}{1-r^2}$ with r the correlation coefficient between global mark percentage and students' mark intervals and n the number of interval involved. It is important to note that X coefficient confidence level is more than 95% .

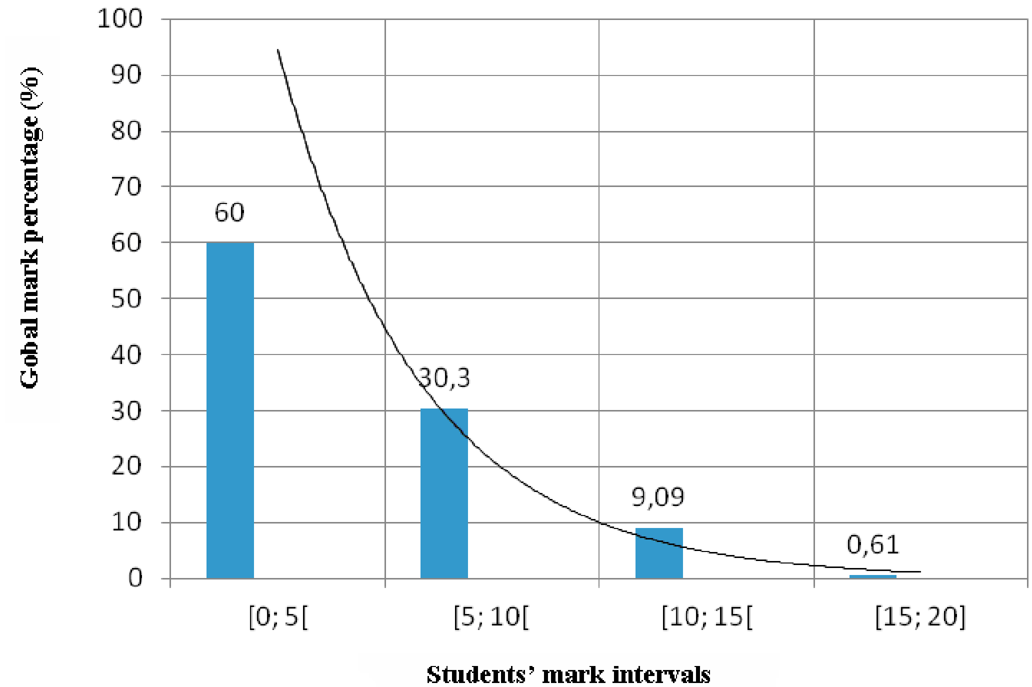

Figure 4 : Students'mark estimation function

The performances per item are given in table 3**.** The indicators of the first hypothesis (see table 1) summarize the objective of the evaluation test. In fact, items E1-E5 correspond to exercise n°1 and items E6-E8 to the three last exercises, respectively. We do not give students' answers for the five items of exercise n°1 for qualitative analysis reason. Only will be given the percentage of success and non success (see table 3). Table 3 analysis highlights that students knew how to use specific light rays to construct (items E6 and E7 in green colour). They were more comfortable with lens (78.79% of success in item E6). They do not succeed in items

E3 and E5 (red colour) and were very uncomfortable with image definition (3.64% of good performance in item E3). This shows that they have no basic knowledge in optics and also means that either they did not learn their lessons or they did not understand anything during their lesson classes. The latter may be true regarding the analysis of lessons observation data. Teachers must help students for optics concepts acquirement for permitting them to be comfortable with name, key criteria and significant examples (De Vecchi, 2000). The percentage of success during this evaluation is 24.02 %. This percentage is better than that obtained during the BEPC sessions 2009 and 2010 (see introduction) but is bad and expresses students' difficulties in class context.

Table 3: Students' performances per item

Codes	Good responses		%	False responses		%
	Number of students	%		Number of students	%	
E1	21	**12.73**	**24.02%**	144	**87.27**	**75.98%**
E2	21	**12.73**		144	**87.27**	
E3	**6**	**3.64**		**159**	**96.36**	
E4	33	**20.00**		132	**80.00**	
E5	**12**	**7.27**		**153**	**92.73**	
E6	**130**	**78.79**		**35**	**21.21**	
E7	**79**	**47.88**		**86**	**52.12**	
E8	15	**9.09**		150	**90.91**	

After the global overview, now we focus our attention to the responses of students in imagery items. We will present one example of success (item E6: figure 5) and two examples of none success (item E7: figure 6 and item E8: figure 7).

The item E6 objective is to construction an image by using converging lens with two specific light rays (see the subject in annexe). In figure 5 we give in panel a one of the three possible responses. In panel a light rays passing by centre and by focus image have been used. Panel b corresponds to student' production. Many students give good responses but they used three light rays in stead of two light rays (figure 5b). This kind of responses shows that they reproduce the solutions previously seen in class. This problem approach expresses the scheme of knowledge (Galili and Lavrik, 1998; Galili and Hawan, 2000)

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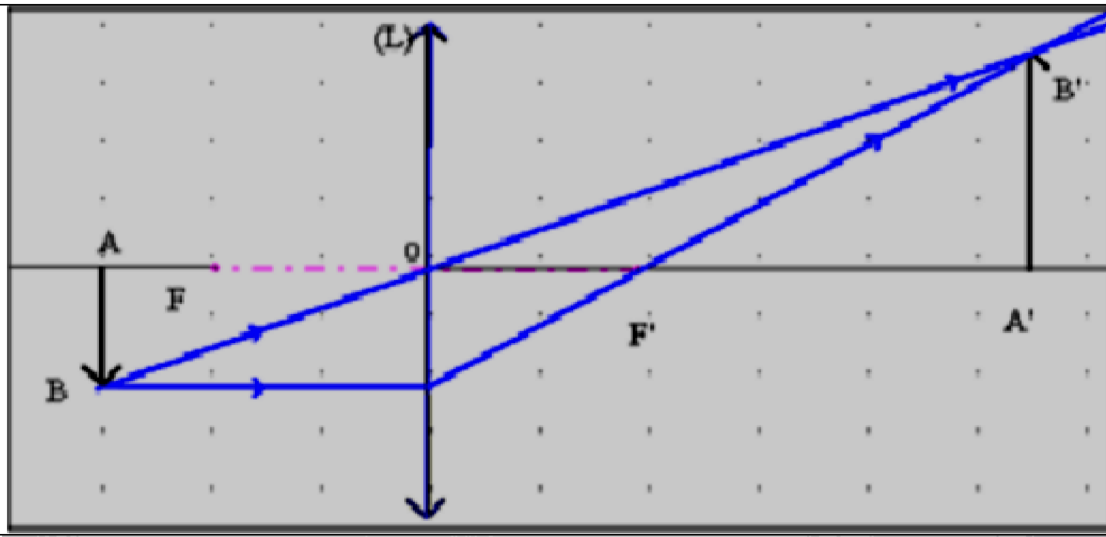
a



b

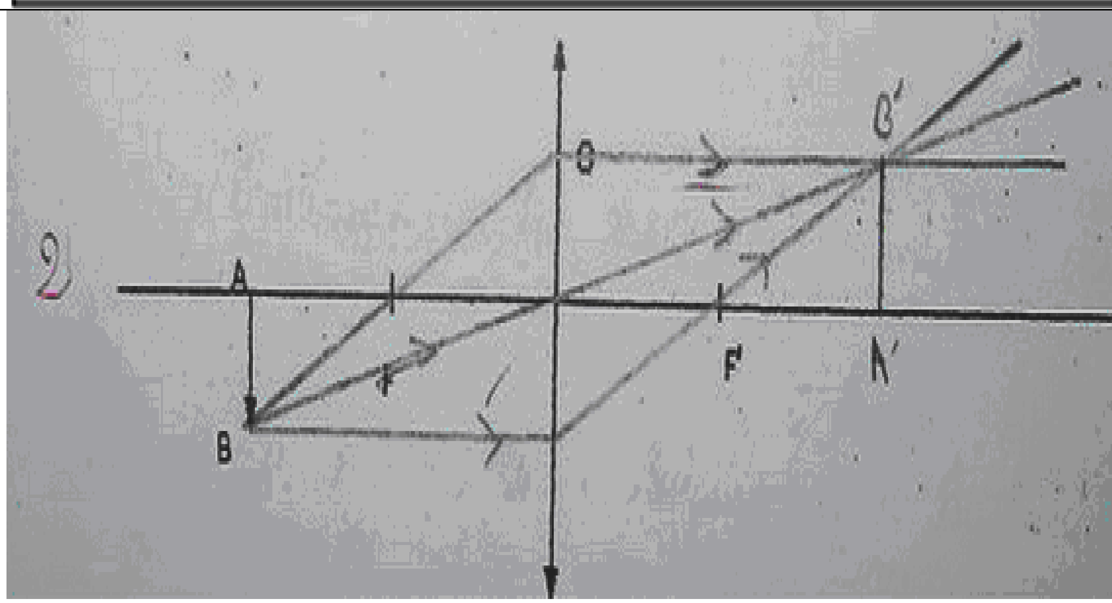


Figure 5: Image construction by using converging lens when knowing object height and position in evaluation context

Panel a of figure 6 gives one of the nine types of solution of the exercise covered by item E7 (see the subject of the exercise in annexe). The scope of this item is to construct object by using converging lens when knowing the height and the position of the image. For obtaining the object position students must use at least two light rays among the three specific well known light rays. In the case of panel a we used the light ray passing by the centre and that passing by the focus image. The only difficulty for students is to remember that light goes from object space to image space even though for the construction we start by the image because it is given.
Panels b-c gives students' false solutions. We only give here the false responses in order to focus the basic problem of students with the concept of light ray. All panels b-c show that students used only one light ray per image point to find object position. This habit comes from class context (see figure 1). We have previously notified that for an object point or an image point, at least two specific light rays are necessary. So by using only one light ray per point students are not capable to obtain the position of the object.

Nevertheless, it is important to underline that students knew the property of each type of light ray. We note here the used light rays properties: (1) Incident light ray passing by lens centre emerges without deflected (see panel a); (2) Incident light ray that is parallel to optics principal axis gives an emergent light ray passing by the focus image (see panels a-b) and (3) Incident light ray passing by the focus object gives an emergent light ray that is parallel to the optics principal axis (see panel c). One can see in panel c that light propagation sense is changed. Student ignored that light goes from object space to image space even if the construction begins by using image. This mistake arrived because there is the lack of experimentation at school. Many secondary schools in Burkina Faso do not have laboratories. This situation explained many students' difficulties during their physics class in general and particularly during optic lessons.

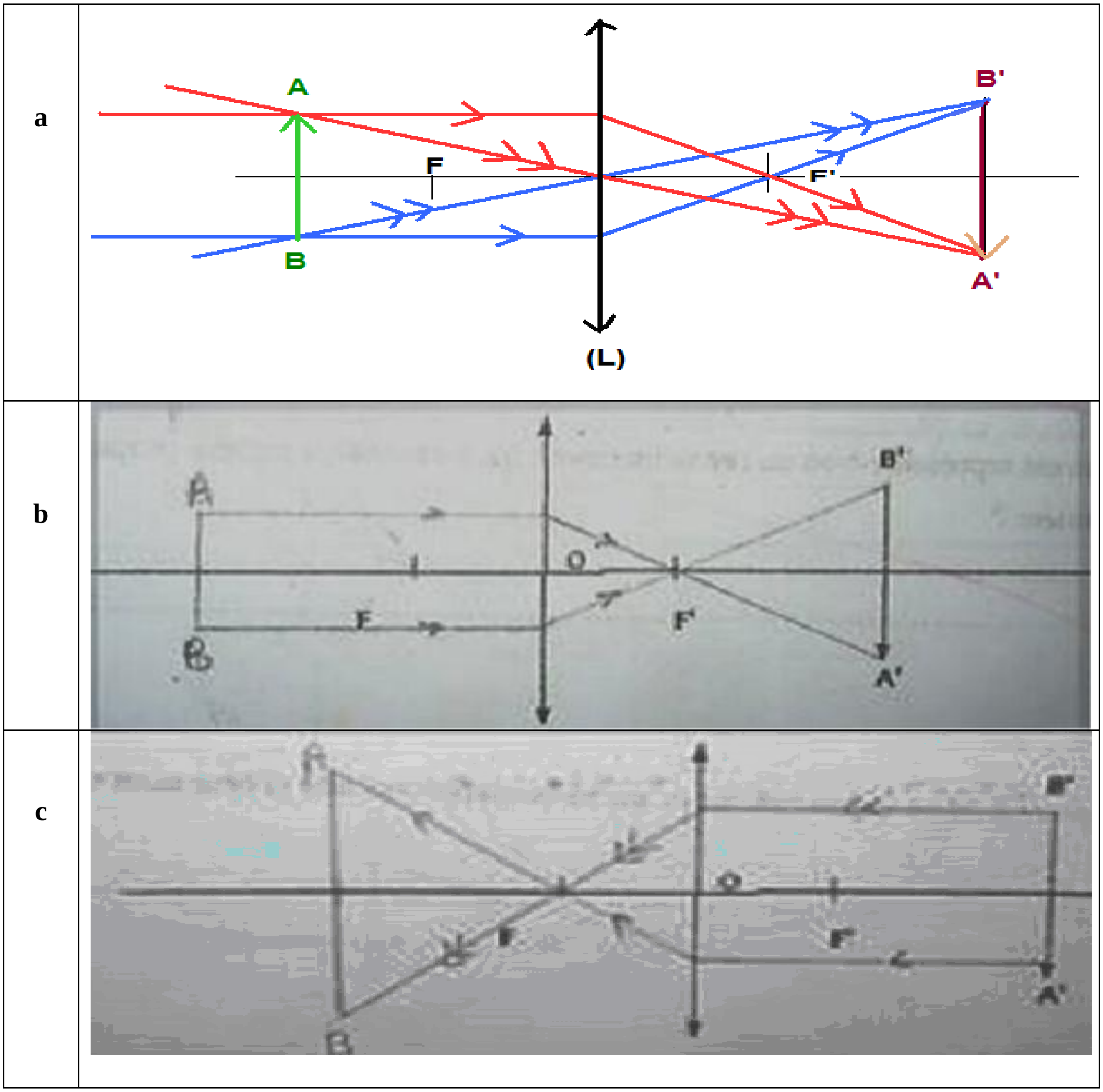


Figure 6: Object construction by using converging lens when knowing image height and position in evaluation context

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Figure 7a is devoted to one of the nine type solutions of the exercise recorded to item E8. The difficulty of this exercise is due to the virtual image given by loupe. Therefore, for constructing image, virtual light rays materialized by dotted lines must be used. To succeed this exercise it is important to know the concept of emergent ray. In figure 7a, we used for object A one ray passing by lens centre and another ray passing by the focus image. For object B we used one ray passing by lens centre and another ray issued from the focus object. The dotted lines correspond to the virtual rays.

Panels b and c concern students' productions. Panel b shows the confusion between virtual and non virtual rays. Only for this student, rays passing the centre are real (full line) and the others are virtual (dotted line). The properties of the particular rays used are correct. Curiously student obtained image with only one ray. This is due to the bad conception used by teacher during class. The bad conception presents the following condition as necessary and sufficient: "***object, image and lens centre are in the same ray light***". This is wrong as the condition is necessary but not sufficient to construct an image. By applying this wrong hypothesis students are not able to find the right image position. One can note the utilization of two other light rays these do not concern the object involved. This panel expresses a hazardous method. In panel c we can note that only the ray passing by lens centre is used.. Moreover, this student does not know at what time ray becomes virtual or not. It can be seen a straight emergent ray coming from A and not passing by lens centre. That ray gives another image B'. It can be retained that panels b and c are the consequences of bad teaching.

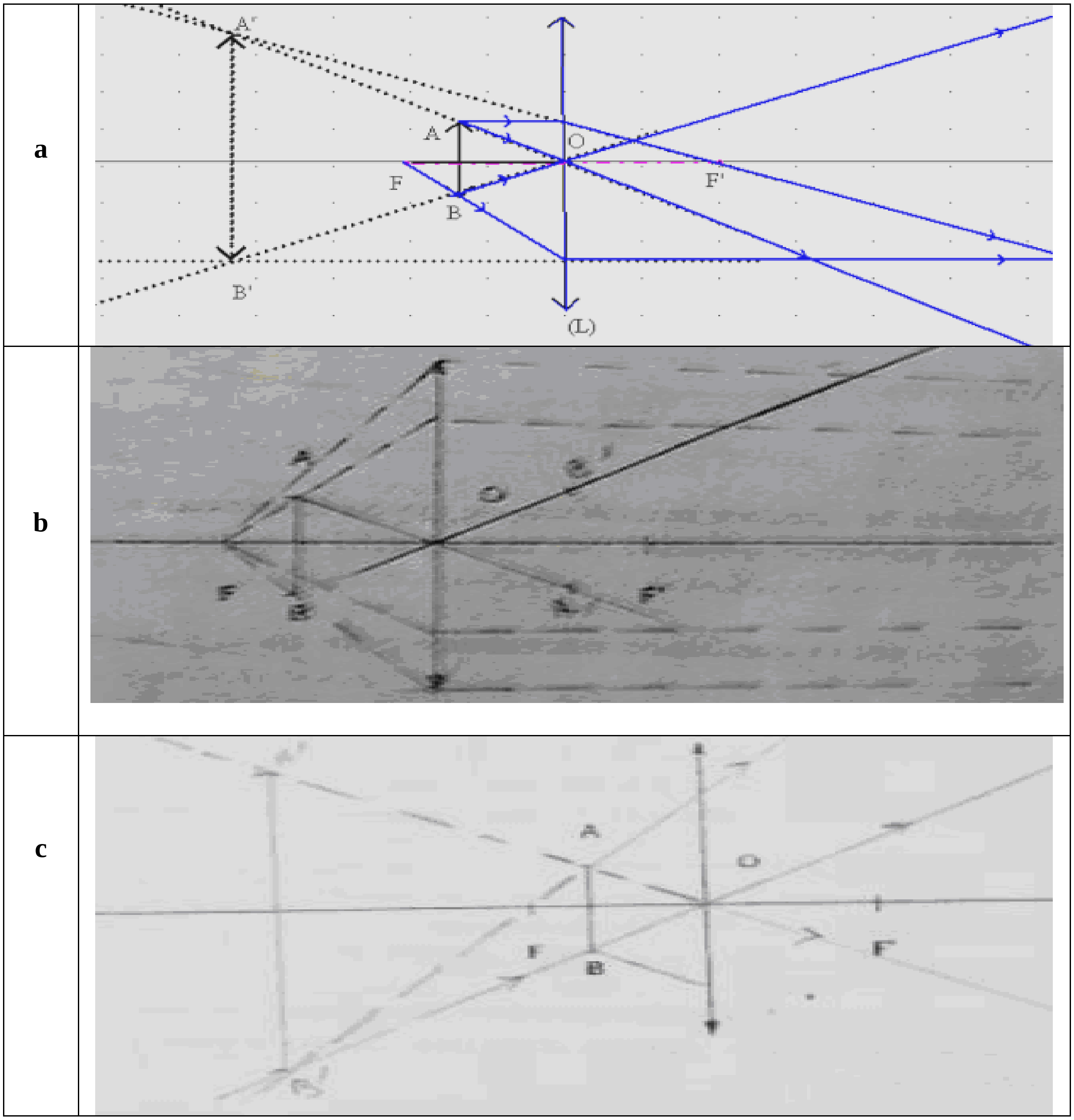

Figure 7: Image construction by using loupe in evaluation context

4.3 Hypotheses testing

The results shown in table 3 and in figures 4-7 confirm our first hypothesis and the conclusions of lesson data investigations carried out by the analysis of figures 1-3 also allow us to assert that our second hypothesis is valid. Therefore, students' poor performance is due on one hand to their misconceptions of light ray and its utilization and on the other hand to bad teaching.

5. Conclusion

Our study showed that student well know the properties of particular light rays but they have confused virtual and non virtual rays for they do not know when ray is virtual ray or not. Students mistake by using only one

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light ray during imagery. The basic concept of light ray in general and particular of emergent ray is not well known. Therefore students' poor performances (24.02% of success) are due to their misconceptions of light ray. Moreover, it has been shown that classroom strategies such as confused schemas, automatically bad utilisation of the principle "object, image and optics centre are in the same light ray" as necessary and sufficient conditions, systematic utilization of only one light ray during imagery, are responsible of students' difficulties in optics class. The complains of first form Physical Sciences teachers and university teachers in optics class due to learners poor performance are justified here. It can be retained that in third form where students begin their optics learning, didactic situations are responsible to their poor performance. Therefore we recommend the improvement of in-service teacher education. As it has been pointed out by class data analysis that students' misconceptions can be overcome by laboratory experimentations, a government policy must be deployed to built laboratories and make them operational for teaching and learning quality.

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Annexure

SUBJECT OF THE EVALUATION TEST

School name: Academic year: 2010-2011

Class number : 3^{rd} …. Date : Duration : 2 hours

First and given names:

Physics Evaluation

Exercise N°1

1) - Define light ray …………………………………………………………………………
   - Give light ray utility? ………..…...

2) Define emergent light ray? …………………………………………………………
3) By using light rays define :

a) real image ? …………………………………………………………………………

b) virtual image ? ……………..

4) Give a necessary minimum number of light rays for image construction…....………

5) How can you represent light ray that does not model real light propagation?
……………………………………………………………………………………………...

Exercise N°2

By using the following figure construct image A'B' that object AB is given by using converging lens

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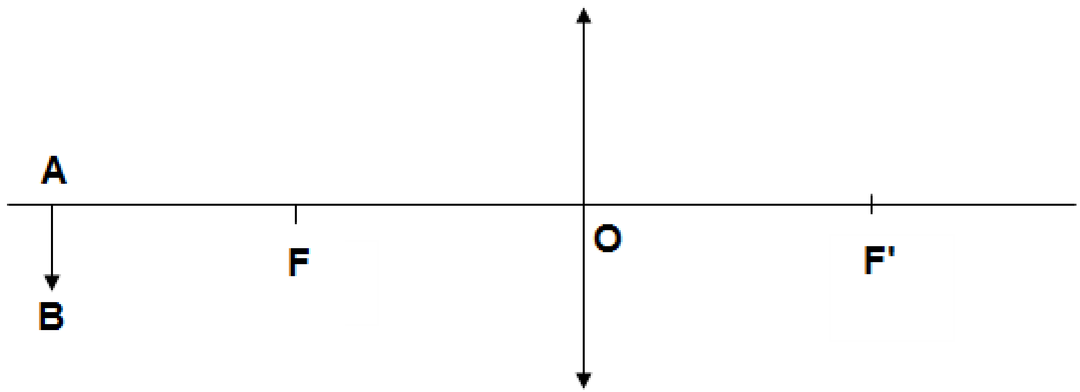
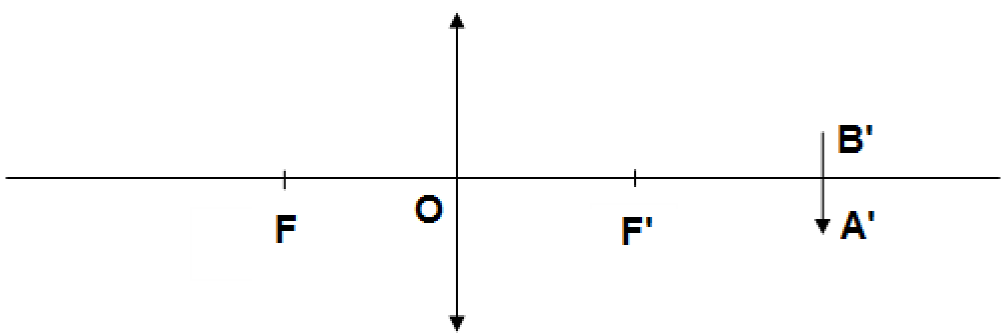


Exercise n°3

Reproduce the figure given below and construct the object AB that image A'B' is given by the converging lens



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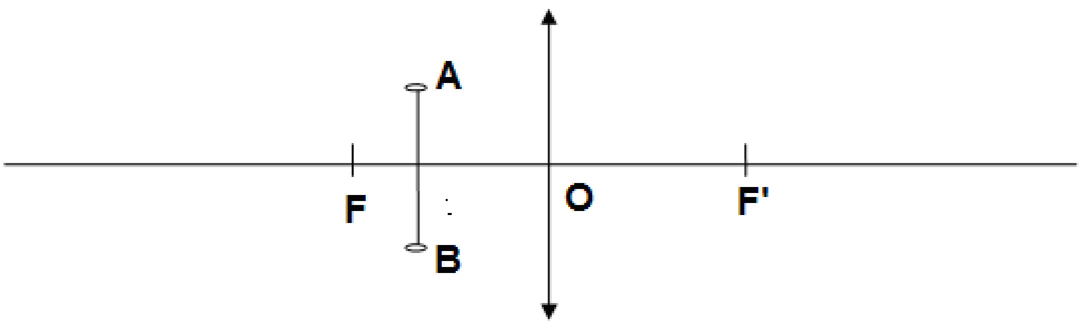
Exercise N°4

Reproduce the figure given below and by:

a) Using one incident light ray passing by lens centre and another incident light ray that is parallel to optics axis, construct the image of the object A
b) Using one incident light ray passing by lens centre and another incident light ray issued from focus object, construct the image of the object B
c) Materialise the image of extended object AB



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