EVALUATION OF VISUAL REPRESENTATIONS IN CLASS 6 NCERT SCIENCE TEXTBOOK

WITH SPECIAL FOCUS ON CHAPTER 11: LIGHT, SHADOWS AND REFLECTIONS

INTERACTION DESIGN SPECIAL PROJECT
IN SPL–79

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Project Approval

The project titled “Evaluation of visual representations in class 6 NCERT science textbook with special focus on chapter 11: light, shadows and reflections” by Saloni Mehta is approved for partial fulfillment of the requirement for the degree of ‘Master of Design’ in Interaction Design at Industrial Design Centre, IIT Bombay.

Guide:

Date: 7. July 2017

Declaration

I declare that this written document represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources.

I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission.

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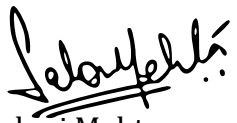

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Abstract

In this project, I have assessed various visual representations used in the Science textbook of the National Council of Educational Research and Training (NCERT) for class 6, for their impact on better understanding of the concepts they represent and are attempting to teach.

At first the entire textbook was assessed generally, and later detailed analyses of each image in the chapter 'Light, Shadows and Reflections' was done informed by responses to a questionnaire designed for and answered by students of CBSE and SSC (Maharashtra board).

It was found that in-spite of the increased focus in recent years on introducing more pictures and colours in textbooks, the current images are not very effective in aiding learning outcomes like understanding of concepts or removing misconceptions. Some design insights are discussed to help move towards this goal.

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Introduction

Visual representations such as photographs, diagrams, illustrations and even textual formatting are essential for supporting student comprehension, retention, and application in education.

Visual representations are not only used to fill up space and to look pretty, they help in better learning because they stimulate the student's spatial intelligence, increase the motivation to learn, betters the scope for dialog and teacher-student and student-student discussions.

The purpose of image varies slightly with what subject is being taught. In science especially one of the primary purposes is to help clarify and build an accurate conceptual model of the concepts being taught.

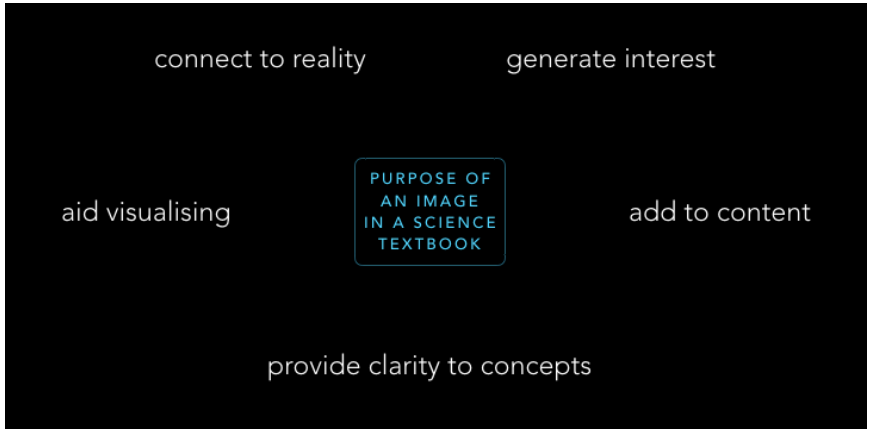


Figure 1 The purpose of an image in a science textbook

Methodology

The book under review here is NCERT's Science textbook for class 6. After a general review of the whole textbook, in depth analysis was done for chapter 11: Light, Shadows and Reflections. The chapter has a total of 12 images. For each image in the chapter, a list of questions (38 in total) were generated (refer Appendix A) under these categories:

1. Literal – visual: What and why
2. Conceptual: How and why
3. Concept application

A total of 52 students from 8 schools were asked to answer these across 5 test locations in Powai, Mumbai, India. The images provided to them for reference fell under two categories – with caption and without caption. These were randomly distributed among students. Questions to a total of 448 images (copies of the 12 original images) were responded to. These are analyzed and reported in later sections.

Table 1 Participating student's education board and class

Board - Class	Student Count
CBSE	21
7	21
SSC	31
6	9
7	21
8	1
Total	**52**

Table 2 Number of students who responded to any question corresponding to an image

	Without Caption			With Caption			Grand
Image	CBSE	SSC	Total	CBSE	SSC	Total	Total
1	10	12	**22**	10	13	**23**	**45**
2	9	10	**19**	10	13	**23**	**42**
3	9	12	**21**	10	12	**22**	**43**
4	9	12	**21**	10	12	**22**	**43**
5	9	10	**19**	10	13	**23**	**42**
6	9	10	**19**	10	12	**22**	**41**
7	9	9	**18**	9	10	**19**	**37**
8	9	8	**17**	9	10	**19**	**36**
9	8	5	**13**	8	10	**18**	**31**
10	8	10	**18**	6	8	**14**	**32**
11	8	9	**17**	5	5	**10**	**27**
12	8	8	**16**	5	8	**13**	**29**
Total	**105**	**115**	**220**	**102**	**126**	**228**	**448**

Note that SSC board schools do not use NCERT textbooks for instruction. Hence these 31 students have had no prior interaction with these particular images. They have however been taught similar concepts using alternate visual representations. Hence, if the images under study were all pervasive representations of the concept at hand, these students can be expected to 'read' these images as well as any other. The CBSE students are all students of class 7, i.e. a year has passed since they have 'studied' these images during lectures. This would allow us to understand how well the images are able act as trigger to memory.

Key Findings

A general review of the whole textbook

At first, the number of visual representations in the entire textbook was counted (refer Appendix B: Across the Textbook). There are a total of 60 real life photographs, 137 illustrations, 22 mixed images (photo + illustration), and 12 3D models spread across the 16 chapters. In addition to these, there are also 39 tables.

Captioning

Chapter 1 'Food: Where does it come from?' is the odd one out, in the way that none of the images are captioned. They float about the text around where related terms and concepts are mentioned. Herein, the images are used to teach more about what concept they are an example of and not so much as what they literally are. For example, a squirrel chewing on some grass is used as an image to represent the concept 'herbivore'.

Note that, in such images, there is no attempt to ensure that a student recognizes the image as 'squirrel', the picture detail quality is bad, and there is no captioning or labeling.

In the other chapters, almost all images are labeled as 'Fig. x.y' wherein x is the chapter number and y is the figure number within the chapter. Similarly for tables, it is 'Table. x.y'.

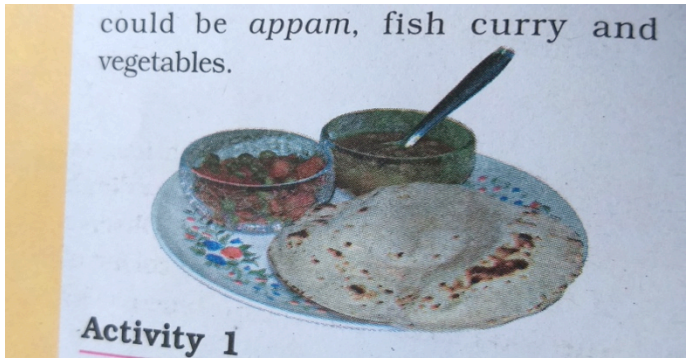


Figure 2 Example of a real life photograph

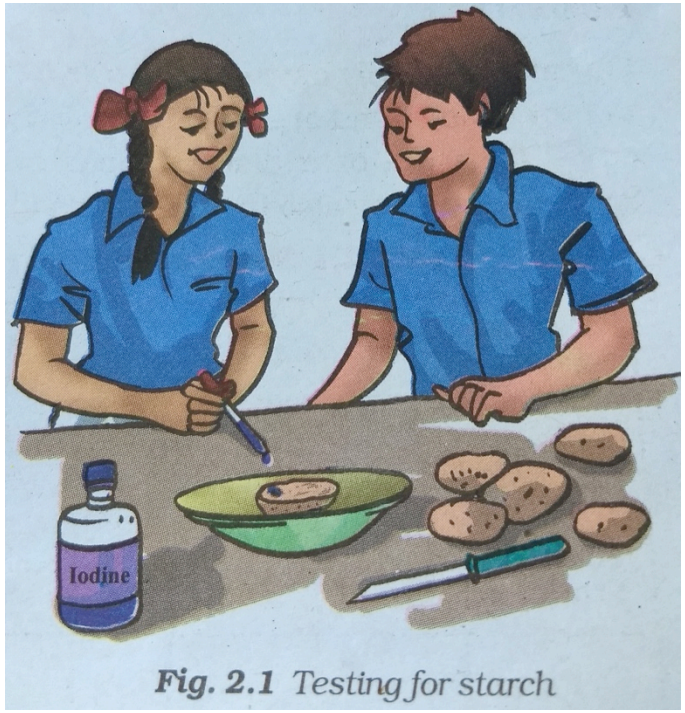


Figure 3 Example of an illustration

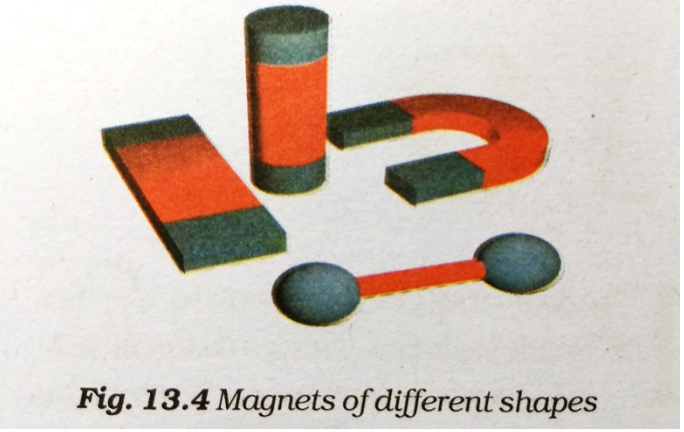


Fig. 13.4 *Magnets of different shapes*

Figure 4 Example of a 3D model

Table 5.2

Substance	Number of spoons of substance that dissolved in water
Salt	
Sugar	

Figure 5 Example of a table

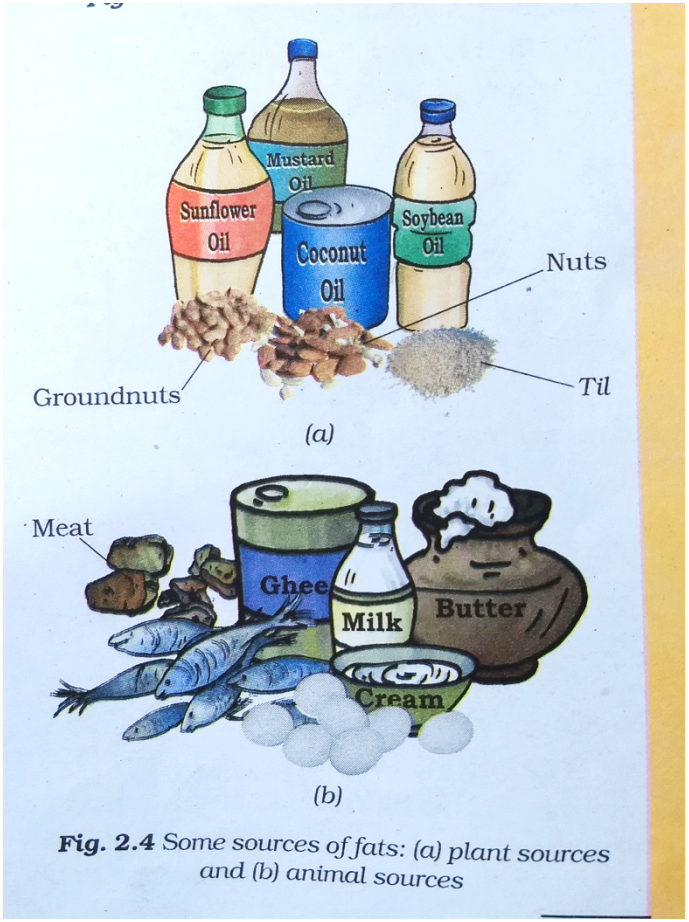


Fig. 2.4 *Some sources of fats: (a) plant sources and (b) animal sources*

Figure 6 Example of a mixed image

Use of Colours

A variety of colours are used throughout the book to imitate the real colours of the constituting entities and their popular imagery. Colour is also used in the rest of the book to indicate chapters, headings etc. Text formatting is also used to compliment the use of colours, and help mark out key words introduced in the chapters.

Use of colours is chapter dependent. Refer Figure 5, the green on the right edge is indicative of the section you are in. The background gradient for tables and the colour of the heading for each chapter also depends on this 'chapter colour'.
Note however that, there is no key to this colour code in the index (or anywhere else in the textbook).

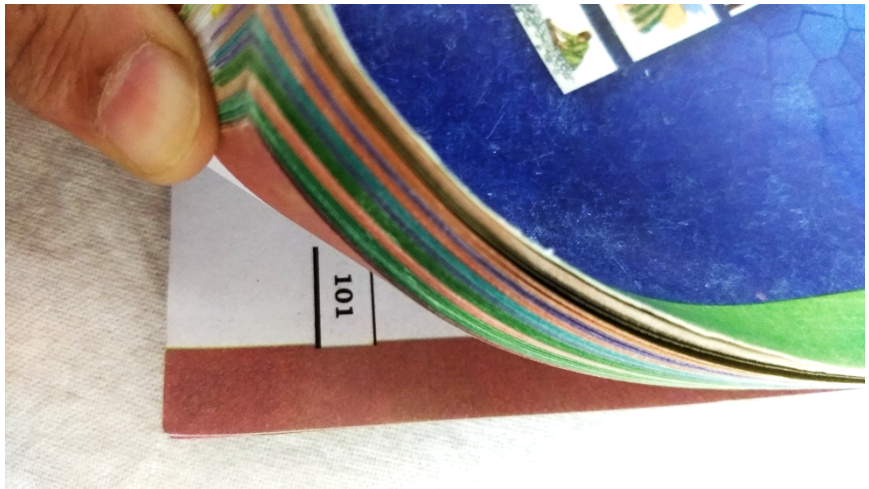


Figure 7 Edge of the pages use colour to indicate chapter

Boojho and Paheli

Boojho and Paheli are characters that accompany the students throughout the book, asking novel questions urging the students to think beyond what is taught. These questions don't have answers in the textbook, and are often open-ended questions with no correct answer. Many a times, they also echo what a child might be thinking, breaking the otherwise tall wall of the 'stupid question'. The idea is to encourage them to discuss science everywhere, especially outside the classroom.

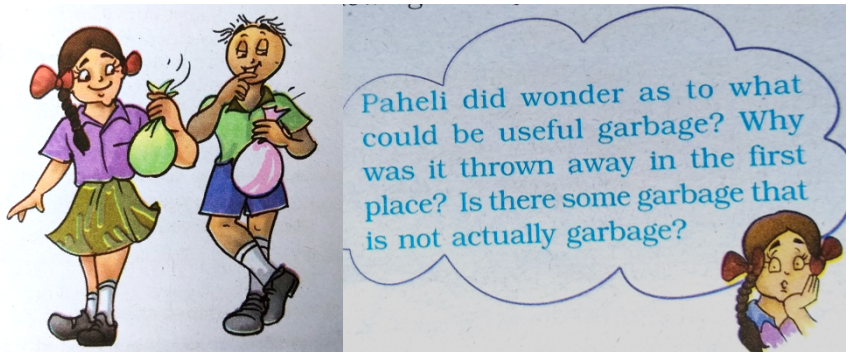


Figure 8 Boojho (the boy) & Paheli (the girl)

Images in Ch.11: Light, Shadows and Reflections

Image Wise Evaluation

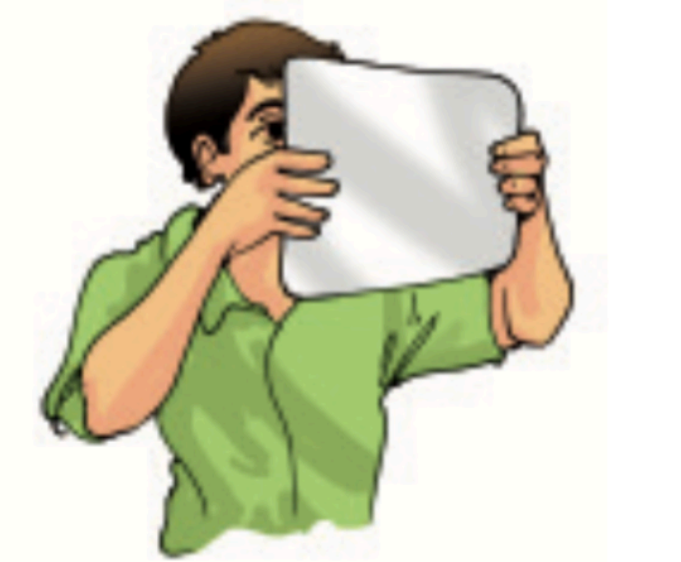


Fig. 11.1 *Observing objects that do or do not allow light to pass through them*

Figure 9 Chapter 11 Fig. 11.1

Number of students who answered the question set:
45 (22 without captions and 23 with captions)

Key Observations:

- Student responses to "What do you see in this image?" were very similar irrespective of the presence or absence of captions.
- 23/45 students (51%) identified the object in the image as a mirror, 12/45 students (26.7%) identified it as glass.
- The grey markings on the object was perceived to be the "shine", and
  The posture of the character led a majority of the students to think of the activity as "looking into the mirror".
- Another common answer (7/45) was paper.

Understanding of the underlining concept: Opacity and transparency.

- Answering questions triggered use of jargon like 'opaque', 'transparent' or 'translucent' in 18/45 students (40%).
- 53.3% students responded saying the character in the image couldn't see through the object. This was heavily dependent on the properties of the material they had earlier identified the object to be made of.

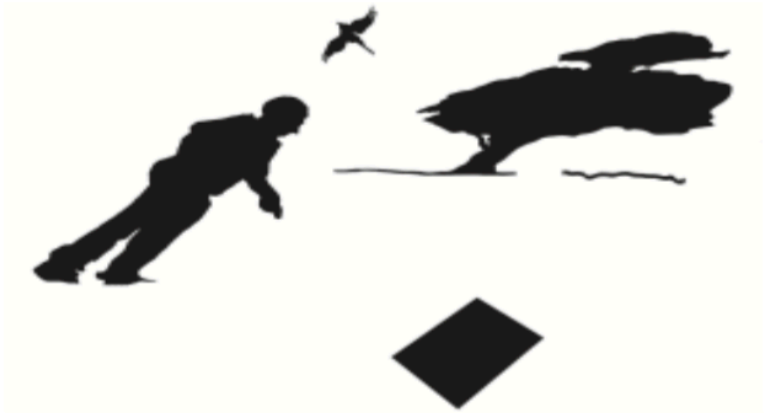


Fig. 11.2 *Sometimes shadow of an object gives an idea about its shape*

Figure 10 Chapter 11 Fig. 11.2

Number of students who answered the question set:
42 (19 without captions and 23 with captions)

Key Observations:

- Most students (26/42 or 62%) identified the image to be a set of distinct entities - a man, a bird, a tree and various interpretations of the diamond shaped shadow. At-least 6/42 students (14.3%) interpreted it to be a set scene due to proximity (Example: Man pointing to the box on the ground while the bird flies above the tree).
- Interpretations for the diamond shaped shadow ranged from the not-very imaginative - square and rectangle to more 3D but yet very simply accessible objects like books and boxes.

Understanding of the underlining concept: Shadows and their relation to the shape of the object.

- Over 88% (37/42) students were able to apply the learned concept to other objects of their choice.
- Students also drew additional conclusions from the shapes of the shadows (Example: the tree is moving in the wind).

Though this cannot be completely attributed to the image, since it's a phenomenon very common to everyday life, the image's ability to trigger correct applications serves the purpose of the image.

Fig. 11.3 *A shadow is obtained only on a screen*

Figure 11 Chapter 11 Fig. 11.3

Number of students who answered the question set:
43 (21 without captions and 22 with captions)

Key Observations:

- Most students (33/43 or 77%) identified the image to be an activity, and try to describe the activity in response to what they see in the image.
- Key words like 'playing' and 'talking' are used by over 21% students to describe the activity
- Identifying the material of held by the leftmost girl-
    - Cardboard - 6 students
    - Paper - 6 students
    - Screen/ surface/ cloth - 7 students (3 without and 4 with captions)
    - Glass - 2 students
    - Mirror - 4 students (indicating confusing shadows and images)

Understanding of the underlining concept: Capturing shadows on screens.

- Only 4/43 students (9.3%) displayed good understanding of the concept.

Issue:

- The image wrongly depicts the shadow forming only on the object held by the leftmost girl. A part of the shadow should also be on her skirt and on the ground (which is completely missed by skipping detailing of the floor.
- It should have been lighter around the shadow on the screen, to show the unblocked light that did reach it.
- This leads to the misconception that there is no shadow if there isn't a screen. It also stereotypes the screen as a rectangular object, instead of any non-transparent object.

Fig 11.4 *Shadows of animals hidden in your hand*

Figure 12 Chapter 11 Fig. 11.4

Number of students who answered the question set:
43 (21 without captions and 22 with captions)

Key Observations:

- 34/41 students (84.93%) identified the image as something they had tried.
- 42/43 students (97.7%) could describe the contents of the image or the activity when asked to describe the image.

Understanding of the underlining concept: Using shadows of objects to imitate shadows of other objects.

- 27/43 students (62.8%) could apply this concept beyond using hands for forming animal shadows.
- Using an application that is a common game has worked in the favour of the image.

Issue:

- At the bottom (where a child is shown making the shadow animals), the absence of a light source (or a ray diagram) confuses students between the concepts of image and shadow formation.

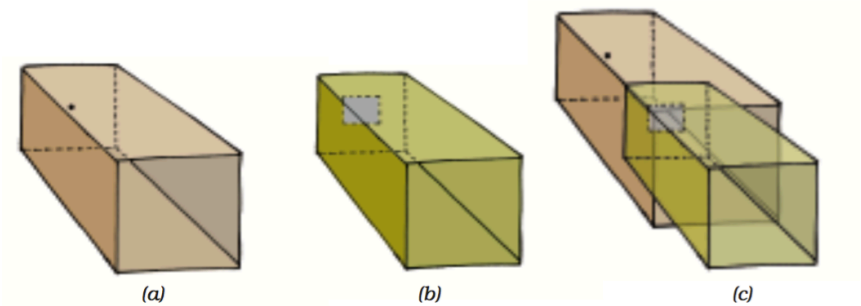


Fig. 11.5 *A sliding pin hole camera*

Figure 13 Chapter 11 Fig. 11.5

Number of students who answered the question set:
42 (19 without captions and 23 with captions)

Key Observations:

- Only 4/19 students (21.1%) could identify what was being built without the caption. With caption (which itself is what is being built) the number increases to 10/23 students (43.5%)
- From the image, students identified the key component to be a 'box' that was made of either cardboard or paper.
- 3/42 students (7.1%) thought it involved mirrors to make the pinhole camera. One student even used the caption to infer that the boxes would hold a camera.

Understanding of the underlining concept: Making of the pinhole camera.

- Diagrammatic instructions to making a pinhole camera aren't clear.
- How this DIY instrument would finally be used (or even the fact that this is an instrument) is beyond the scope of this image.

Issue:

- The materials used should be clearly labeled.
- Due to the see-through-the-layers illustration style, and absence of any real image of the final product, it led some students to believe the material used was glass.
- From the image (or caption) itself it is not clear that the image has the steps to make a pinhole camera. There is no indication of a procedure.

Fig. 11.6 *A natural pinhole camera. Pinhole images of the Sun under a tree!*

Figure 14 Chapter 11 Fig. 11.6

Number of students who answered the question set:
41 (19 without captions and 22 with captions)

Key Observations:

- In response to what they see in the image, most students only responded with entities like tree (49%), shadows (39%), road (22%), park/ground (7.3%)
- When specifically asked to explain the white spots below the tree, 25/41 students (61%) did attribute it to sunlight and 13 others (32%) identified them as gaps in the shadows of the leaves, but almost no one could identify them as pinhole images of the sun.

Understanding of the underlining concept: Real life examples and applications of pinhole cameras

- 25/41 students (61%) didn't understand the working of the pinhole camera at all.

Issue:

- Pinhole cameras and images are a complex application to understand since students rarely come across real life examples. An overlay of a ray diagram would have worked much better to explain how the spots were images of the sun. Images of alternate examples would have also helped.
  In fact, the pinhole part of the image (the tiny gaps between the leaves) has been completely forgone.

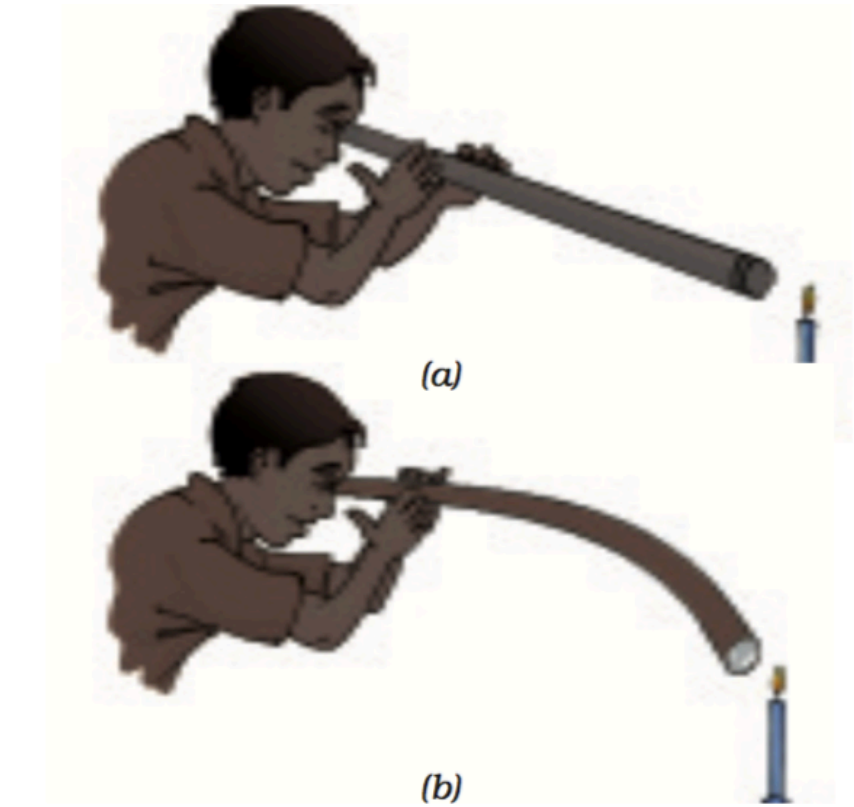


Fig. 11.7 *Looking through a pipe pointed (a) towards and (b) a little away from a candle*

Figure 15 Chapter 11 Fig. 11.7

Number of students who answered the question set:
37 (18 without captions and 19 with captions)

Key Observations:

- Most of the SSC board students (who were seeing this particular image for the first time) couldn't correctly identify the components or the activity the image depicts. Some thought of the pipe as a binocular. Another described the activity as 'the boy is trying to burn the tube'.

Understanding of the underlining concept: Light travels in a straight line

- 25/37 students (67.6%) correctly answered that in (a) the character will be able to see the candle. However, all the 12 students who answered wrong or couldn't answer were from SSC board schools. This indicates that the image by itself fails to demonstrate the underlining concept.

Issue:

- For first time viewers of an image, the caption serves the key purpose of explaining what the image is about. Here, the caption itself is misleading. Instead of saying "(a) straight pipe and (b) bent pipe, both pointing towards the candle", the caption says "pointed (a) towards (b) a little away from the candle." This an error, and doesn't accurately describe the experiment.

Fig. 11.8 *A mirror reflects a beam of light*

Figure 16 Chapter 11 Fig. 11.8

Number of students who answered the question set:
36 (17 without captions and 19 with captions)

Key Observations:

- 25/36 students (75%) either identified the activity of the underlining concept of the image, when describing the image. The presence or absence of captions did not significantly effect image perception.
- Presence of both genders in a single image is a plus. One student ended up using gender neutral language "he/she" while answering the questions.
- The torch was correctly identified. Multiple students referred to it as 'batry' as used in their local lingo.

Understanding of the underlining concept: Reflection of light and direction of reflected light.

- 18/36 students (50%) understood that if the third character were also holding a mirror, the reflection would go on. The orientation of the kids made 14 of these 18 students to estimate that the light would reflect back to the first character.

Feature:

- The flow of light, and character orientations helped students identify relative positions and estimate direction of light flow, in alternate scenarios.

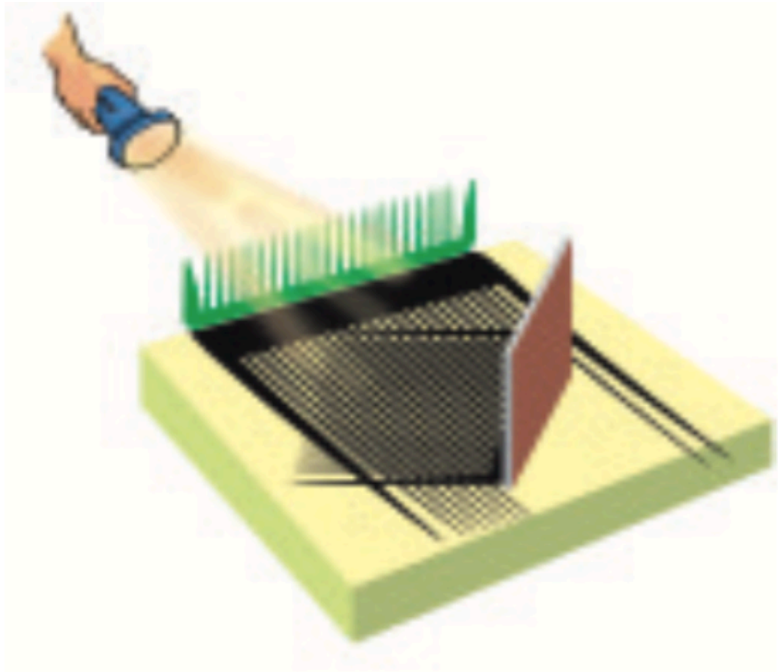


Fig. 11.9 *Light travelling in a straight line and getting reflected from a mirror*

Figure 17 Chapter 11 Fig. 11.9

Number of students who answered the question set:
31 (13 without captions and 18 with captions)

Key Observations:

- 5/16 CBSE students (31.3%) were able to identify the object 'comb'. 0/15 SSC students (0%) were able to identify the same.
- 7/31 students confused the mirror in the image with a book, a card, a laptop by the window, a block etc. The caption did not seem to help even though it contains the word 'mirror'. Even the CBSE kids got confused with the mirror, even though they recognized the comb.

Understanding of the underlining concept: Reflection of light and shadows.

- 15/31 students completely left the applicative question. The ones who did attempt drawing the same diagram with an object other than the comb went severely wrong.
- Only 2/31 students could apply the concept by replacing the comb.

Issue:

- The language of the image is not clear. The image could have been a real photo. The illustration has gone wrong with the shade of the shadows in the lit area, rendering the criss-cross of black lines at the base with no realistic character.

If A is not able to see B in the mirror, then, is B able to see A in the mirror?

Similarly, for any two pairs amongst A,B,C, or D?

Fig. 11.10

Figure 18 Chapter 11 Fig. 11.10

Number of students who answered the question set:
32 (18 without captions and 14 with captions)

Key Observations:

- 15/31 students (47%) incorrectly identified the object in the child's hand.
  8 students thought it was a magnifying glass. 6 of these 8 students were from CBSE, who have learnt the lesson using this image.
  Other attempts at identifying this object included 'toy', 'ball', 'chalni' (sieve).
- Because of the formation, multiple students described the activity as PT exercise.

Understanding of the underlining concept: Reversibility of light.

- The image does nothing much to help understanding of the concept. Only 13/32 students (40%) got the applicative questions right after revealing that the object in hand was a mirror.

Issue:

- Effect of form on identification of an object, especially with a preconceived idea as per the cultural context
- The key requirement to understand this concept is relative positioning, which is not clear in this perspective drawing. A student even perceived the perspective drawing to be height-wise standing.
- This image is heavily dependent on teacher instruction.

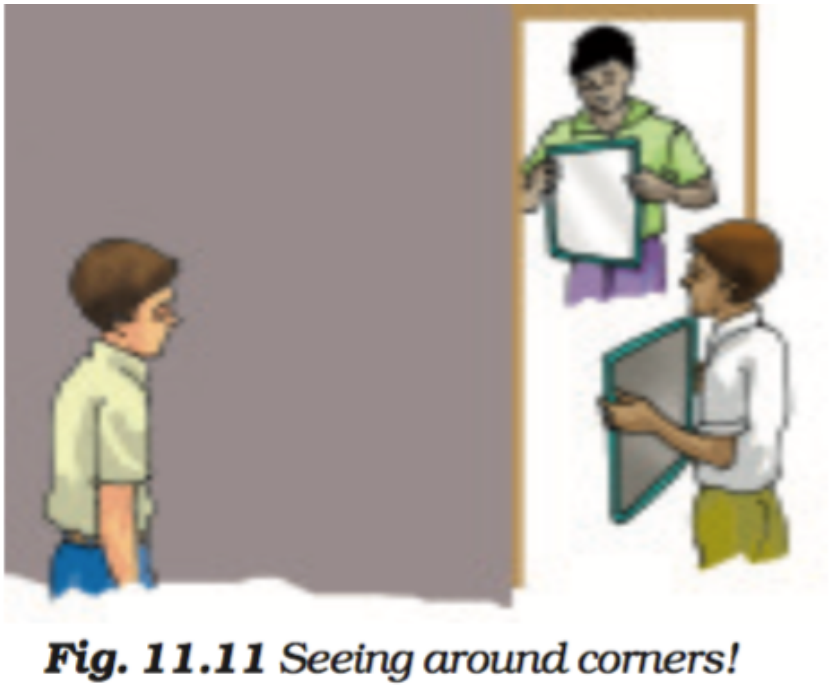


Fig. 11.11 Seeing around corners!

Figure 19 Chapter 11 Fig. 11.11

Number of students who answered the question set:
27 (17 without captions and 10 with captions)

Key Observations:

- Most students (22/27) were able to identify the entities like mirror, boy, wall in the image.
- 13/27 students (48%) accompanied the description with the relative positions of the entities in the image.

Understanding of the underlining concept: Using multiple reflections to see around corners.

- 14/27 students (52%) were able to apply the concept to a scenario.

Issue:

- In the imagery, it is possible to confuse the door with a larger mirror in which the boy with the mirror is seeing his own reflection. Better semantics could be used to indicate a door. Or the person on the other side could be another gender.
- No reflection is shown in the mirrors. Ideally, the mirrors should be reflecting whatever is behind the wall.

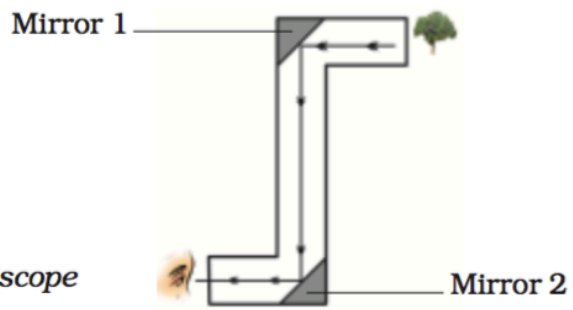


Fig. 11.12 *A periscope*

Figure 20 Chapter 11 Fig. 11.12

Number of students who answered the question set:
29 (16 without captions and 13 with captions)

Note: Periscope as such is not covered in SSC Class 6 syllabus

Key Observations:

- While describing the image, the students tried to list the entities they saw. The tree was easily recognized, but there was some confusion in recognizing the human eye.

Understanding of the underlining concept: The working of a periscope.

- 10/13 CBSE students (76.9%) understood how image formation would change given that a mirror was removed. This number was 5/16 for SSC students (31.3%).

Feature:

- Presence of a clear ray diagram and labeling for the mirrors ensured that even students who were seeing the image for the first time could understand how the device was working.

Issue:

- It is not clear what the eye would eventually see.
- The example used is not the best use case of a periscope. If a scenario of real need was depicted, the utility would instantly be communicated.

Design Insights

From the analyses and learning we can derive these design insights –

1. Form of the image entity effects identification. Visual representations should be made keeping in mind popular cultural references.
2. Use overlaying identifiers like ray diagrams, labeling etc. to ensure no confusion in interpreting what the image is. Also aids understanding of concepts.
3. Visual cues like texture, pattern, perspective and posture effect identification. The illustrations need to be made in cognizance of this.
4. Images are often used a mental bookmarks.
5. Use images of activities students can try
6. Show alternates, what happens if things change?

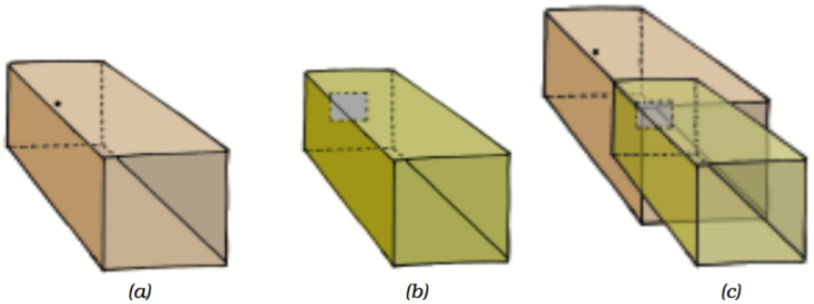
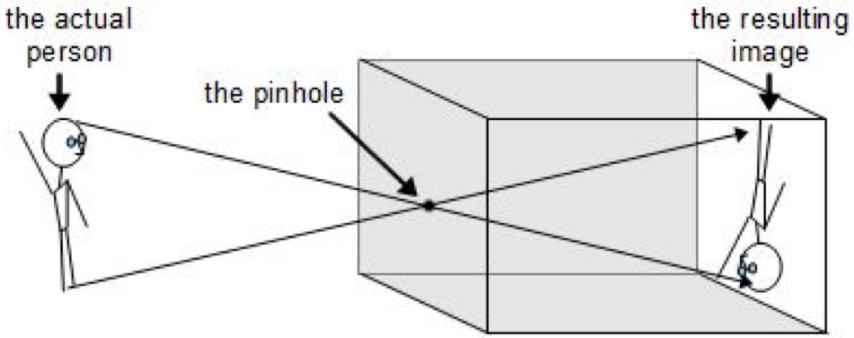
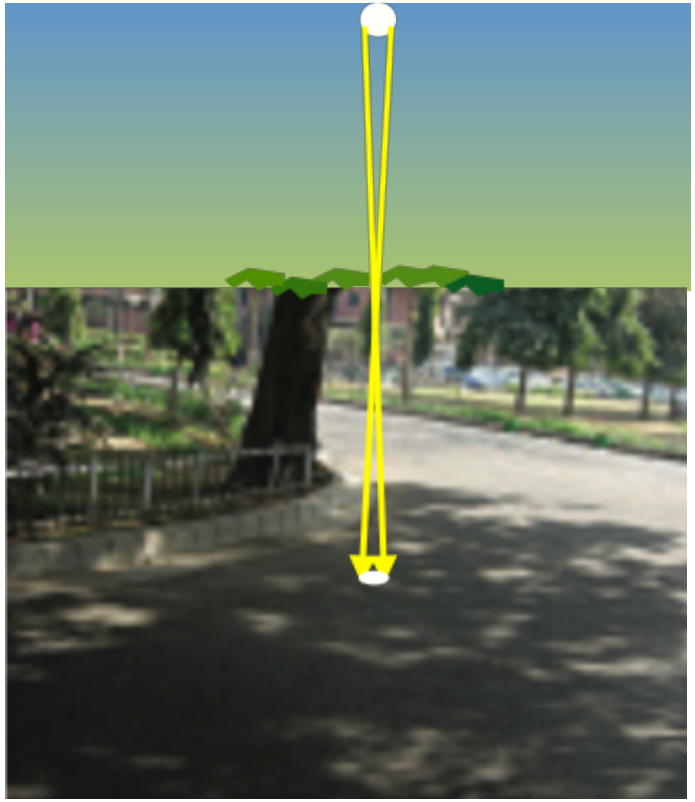


Fig. 11.5 *A sliding pin hole camera*

(a) Original image depicting the making of a pinhole camera from the NCERT textbook



(b) Working of a pinhole camera with labeling and overlaid ray diagram. (Image source: http://rimstar.org/)



(c) A pinhole camera in nature. Ray diagram overlay over original image from the NCERT textbook

(d) Activities students can try to play with pinholes (will need detailed captions and a 'how-to-do' in the textbook)
(Image sources: 3c1703fe8d.site.internapcdn.net/ and www.hartrao.ac.za)

Figure 21 (a), (b), (c) and (d) Images related to teaching the Pinhole Camera

Concluding Discussion

A lot of focus has been given to improving the visual representations used in textbooks. This has translated to more pictures per chapter and more colours per picture. It has also led towards more gender equal and race equal visual representations (For example, the chapter under study had 13 boys and 5girls across 12 images, and students of various skin colour).

However, adequate care to the content of the imagery is still not being given. The imagery correlates directly with the content being taught. Images are treated as an aid to understand content, and not content themselves. This needs to change.

While understanding concepts, children form mental models. These can often be wrong and lead to sever misconceptions. It is of utmost importance that images play their part in busting these misconceptions. For example, most children confuse between a shadow and an image. As adult content makers we think of these as obvious and simple concepts. But data shows otherwise. None of the images address clearing this misconception.

Captions and labels are very integral parts of imagery. However, today text in images is given a back seat, leading them to be very unhelpful and in some cases properly erroneous. Though, it was observed, that very similar responses were received irrespective of the availability of captions, this was more so because of very non-descriptive captioning.

The more complex the concept, the more particular-image specific the learning becomes. In science, images are an important way of understanding concepts and how we experience those concepts in real life. In light, since we are usually not seeing these rays of light, and don't use pinholes cameras and periscopes, these become foreign concepts to us. This textbook–reality gap, hence becomes the onus of the images to bridge. We need to pay more attention to them.

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Appendix A: The Questionnaire

Image	Caption	Question 1	Question 2	Question 3	Question 4
1	Observing objects that do or do not allow light to pass through them	What do you see in the image?	What material is the kid holding? Why do you think so?	Can the kid see through it? Why do you think so?	Could the kid see through if the material was made of - glass?, paper?, copper?
2	Sometimes shadow of an object gives an idea about its shape	What do you see?	Draw the objects these shadows belong to	Draw any object you like. Draw its shadow	
3	A shadow is obtained only on a screen	What are these kids doing?	Why are they in the dark?	What is the girl in the back holding? What if she was not holding it? Draw.	
4	Shadows of animals hidden in your hand	What do you see in the image?	Have you tried this yourself?	What other objects can you use to do this?	
5	A sliding pin hole camera	What do you see in the image? Do you know what it is used for?	What materials are required to make this?	Can you make this with shoeboxes?	
6	A natural pinhole camera. Pinhole images of the Sun under a tree!	What do you see in the image?	What are the white spots on the ground?	Where else do pinhole cameras exist in nature?	
7	Looking through a pipe pointed (a) towards and (b) a little away from a candle	What is the kid trying to do in the picture?	In which case (a) or (b) will he be successful?	What if the tubes were lined inside with small mirrors?	

8	A mirror reflects a beam of light	What do you see in the image?	What else could the girl be holding for the same thing to happen?	What would happen if the other boy was also holding a mirror? Draw.	
9	Light travelling in a straight line and getting reflected from a mirror	What do you see in the image?	Why is there a crisscross of black lines?	What could we use instead of the comb? What would the image look like? Draw and show.	
10	If A is not able to see B in the mirror, then, is B able to see A in the mirror?	What do you see in the image?	What is the boy holding?	If A can see C in the mirror, then, can C see A in the mirror?	If A is not able to see B in th mirror, then, is B able to see in the mirror?
11	Seeing around corners!	What do ou see in the image?	What is behind the wall?	If there was a tree behind the wall, what would you see in the mirror? Draw in the image.	
12	A periscope	What do you see in the image?	What can you use this for?	What would you see if the 'Mirror 1' wasn't there?	

Appendix B: Across the Textbook

Table 3 Count of visual representations for the entire textbook**

Chapter	Photos	Illustration	Mixed*	Model	Table	Total
1	6	4	2	0	7	**19**
2	3	2	5	0	4	**14**
3	8	5	0	1	0	**14**
4	2	6	0	1	4	**13**
5	1	12	2	0	2	**17**
6	0	10	0	0	2	**12**
7	9	12	5	0	3	**29**
8	5	18	0	1	3	**27**
9	5	12	1	0	1	**19**
10	1	13	1	0	4	**19**
11	1	11	0	0	1	**13**
12	9	2	4	1	1	**17**
13	2	9	0	6	5	**22**
14	1	12	0	0	1	**14**
15	1	8	1	2	0	**12**
16	6	1	1	0	1	**9**
Total	**60**	**137**	**22**	**12**	**39**	**270**

* Mixed refers to visual representations which are amalgamations of both photos & illustrations
** These counts do not include the Paheli and Boojho illustrations and thought bubbles spread through the book.

Appendix C: Resources

Collated data file: https://drive.google.com/drive/folders/0BywP2_yNs4eKLWE3YzhUbXJObFE