Available online at www.sciencedirect.com
ScienceDirect
Procedia - Social and Behavioral Sciences 167 (2015) 204 – 210
Procedia
Social and Behavioral Sciences

IOSTE BORNEO 2014

Illustrations in Science Education: An Investigation of Young Pupils Using Explanatory Pictures of Electrical Currents

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Abstract

This study is part of a project regarding explanatory illustrations in science education. Research questions here concern how pupils use and make meaning from illustrations in a science textbook. Electricity was chosen as the subject. Video data was collected in 8 sessions, each with a pair of pupils, 10-11 years of age in one school in Sweden. Communication within the pairs and with the interviewer was analyzed. The children also drew a picture of a battery and explained its function using this drawing. The most striking result was an almost complete lack of transparency for the scientific information in the illustrations. Regardless of previous knowledge, pupils were almost never able to collect new information on their own or together with their peer. As long as the visual information matched previous knowledge they could explain the content, but as the complexity increased, they were lost. They then either expressed their incomprehension or carried on to argue for evident misconceptions, not realizing that the illustrations were contradicting them. Together with the interviewer, pupils could eventually identify central scientific messages and where their previous understanding was challenged. One conclusion is that scientific illustrations can drive scientific in-depth discussion. However, the main conclusion is that pupils are not trained to interpret multimodal information themselves and that teachers and textbook authors therefore risk overestimating pupils de-coding abilities.

Peer-review under responsibility of Universiti Teknologi MARA.

Keywords: visual information; explanatory illustrations; science education; electricity; primary school

1. Introduction

Information can be presented and perceived in many ways and consequently the view on literacy has been altered to include visual and multimodal literacies as well (Kress, 2003). Indeed, scientific literacy inevitably includes the

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1877-0428
Peer-review under responsibility of Universiti Teknologi MARA.
doi:10.1016/j.sbspro.2014.12.663

ability to interpret models, symbols, diagrams, graphs and pictures (Lemke, 2000). School science textbooks and other teaching materials for young pupils include and rely greatly on this kind of visual information and explanatory illustrations therefore play an important role both in science and in science education (Gilbert, 2005). Pupils' capacities to interpret this visual information will be of great importance.

Visual information is generally supposed to be an effective way of communicating data and the transparency of visual information seems to be taken more or less for granted (Pintó & Ametller, 2002). However, pupils can be expected to differ in their ability to collect information from illustrations or illustrations in combination with text or speech, i. e. their visual and multimodal literacies (Kress 2003). Studies on how scientific representations are incorporated in science education have so far been directed towards secondary school students (e. g. Wu, Krajcik & Soloway 2001, Cook 2006) or even higher levels of education. Less attention has been brought to younger pupils. Hence, young pupils' use of visual information in science education is a domain that needs investigation.

Several researchers have studied general relationships between text and pictures (e.g. Kress & van Leeuwen 1996, Martinec & Salway 2005). Within the education domain, Lemke (2000) states that the ability to coordinate and make meaning from several modes of information and combinations of semiotic systems is required to understand science education. Information needs to be de-coded, evaluated and reconciled with previous knowledge and what information is actually captured in that process depends very much on the context (Kress 2003). The reason that visual information seems transparent to teachers and textbook authors is that they already know the code (Kress & van Leeuwen 1996). Engebretsen (2012) explores the concepts *cohesion* and *tension* in relation to learning in this multimodal context, stating that the challenge is in the balance between these two. Cohesion lies in the identification of semiotic elements and their relation to previous knowledge, whereas tension would be the opposite; provoking reaction, interaction and engagement. Cohesion is brought from similarity, continuity and proximity. Tension, on the other hand, comes from contrast, distance and discontinuity. The concepts of cohesion and tension apply both to the interplay between modes but also within each mode itself, the text or the illustration.

Central to all this is the question why we would want to combine more than one mode, in this case text and illustrations. It could simply be functional; illustrations and text have different purposes, emotional impression versus logical analysis for instance. Another reason could be that visual information is considered as more transparent for illustration of complex processes. A third possibility is that the text and images follow parallel paths, more or less presenting the same information but possibly appealing to different readers. However, little attention has been directed to exactly what features that make text and images interact to create meaningful multimodal information (Martinec & Salway 2005). Multimodal representations with combinations of text and illustrations naturally make up challenges of some sort to the reader. Even the simplest cases, pictures representing objects in combination with a terminology, demands ability to observe abstractions and make interpretations. When we move into scientific education, illustrations quickly become loaded with complex information. The magnitude of this might not be obvious to a teacher or a textbook author that is already well acquainted with the subject. Readers however, need to distinguish things like processes and movements from images that are static. They need to grasp models, and separate these from what is concrete and naturalistic. Not unusually, models are incorporated into illustrations of concrete situations, like electrons represented by minus signs inside a bulb or a wire. Pupils might also need to notice magnifications and understand cross-sections etc. In school textbooks several of these different features are used simultaneously to represent complex processes and phenomena. The textual information might also be integrated in several different places; labels inside illustrations, separate illustration texts or a parallel main text.

In this study we wanted to explore how primary school pupils make use of scientific information that is presented both in text and illustrations, side by side in the same medium. The study is part of a larger project with focus on explanatory pictures used in science and mathematics education. The project takes a socio-cultural perspective in the Vygotskian tradition and analyses focus on interactions between the pupils, the pupils and the textbook material and between pupils and interviewer. The socio-cultural perspective means that the study leans on the idea of illustrations as mediating interpersonal relations (Vygotsky, 1978). Illustrations are understood as cultural artefacts that obtain their meaning from the historical and cultural context where they are created and used. Representations are processes that take place through social and semiotic interactions (Wartofsky, 1979). They are integral parts of the making of meaning and the appropriation of cultural knowledge. The unit of analysis of studies of meaning-making becomes the social semiotic interaction activities, in this case, the scientific discussions.

2. Aim and research questions

The overall aim of this study is to investigate how primary school pupils make use of scientific illustrations in a school textbook and how these are incorporated in interpersonal interactions.

We specifically ask the following questions:

1) In what ways and under which conditions do illustrations best support pupils understanding of scientific phenomena, processes or concepts and when do illustrations, in contrast, act as pitfalls?
2) How do pupils use illustrations and texts together and what differences are there in ways they do this?

3. Methods

3.1 *Choice of textbook and illustrations*

All discussions revolved around a suite of illustrations concerning electricity and electrical currents in one school textbook that the classes were already using and that is adapted for pupils on this level. Electricity was a subject that the contacted school classes had been working on recently. We wanted the participants to be informed about the subject and thereby the conversations to be fairly in-depth.

The textbook was chosen for two reasons. First, it includes many illustrations on all pages throughout the book. The book is clearly aiming to explain basic as well as complex scientific phenomena and processes both in text and in illustrations. Second, we also wanted the pupils to be familiar with the textbook, with the format and the overall outline. With these conditions we were hoping to go straight into talking science in the interviews.

Seven pages in text book were used in the discussions, each containing one or several illustrations. You could classify these illustrations based on scientific informational complexity. One very straightforward illustration included a closed circuit (the bulb is lit) and an open circuit (the bulb is not lit). A more complex illustration showed a closed circuit with a cross-section of the wire and a light bulb, electrons and arrows indicating direction of the current. The most complicated and elaborate illustration was a cross-section of a battery aiming to explain its internal function. The other illustrations fell somewhere along this gradient of complexity.

3.2 Approach and design of interviews

Data collection was done by video recordings of interviews in settings with two pupils and one interviewer. One school in Sweden was visited in two consecutive years, one class in 2011 and another class in 2012. All pupils were 10-11 years old at the time. All together, 8 sessions with a total of 16 pupils were analysed.

The form for the interviews was open; in order to have the children speaking freely the sessions were directed towards a conversation format with a few elements recurring in all session. During each session the interviewer invited the children to have a discussion about electricity. The textbook was opened on the table in front of them and the participants were informed to use the textbook (text or illustrations therein) in the discussions. In case the children did not consult the textbook, reluctant to do so or doubtful it was actually permitted, they were distinctly and repeatedly instructed to study the pages in the book for answers and input in the discussions. The interviews lasted between 20 and 40 minutes. The pairs of pupils in the interviews were decided solely by their school teacher among the pupils whose parent had agreed to allow participation and also, themselves, were clearly willing to take part.

In most interviews the participants were asked to draw a picture at the end. The instruction then was to make a drawing showing how a battery works and then to use their own drawing while explaining the function. While they were drawing they had the book open in front of them with the illustration of a battery in cross-section and a text alongside explaining how the battery works. The idea here was to investigate what features of the illustration and the text that the pupils incorporate in their drawings and narratives.

Interviews were transcribed, noting speech and gestures. Specifically interesting sections in relation to the research questions were analyzed and pupils' understanding and use of the textbook were categorized.

4. Results

Most pupils were initially unfamiliar with the situation, analyzing visual information of scientific phenomena together with an adult. However, they quickly adapted and many of them did afterwards comment, surprised, on the session as being "fun, actually". Typically the atmosphere of the interviews shifted within a few minutes from examination to relaxed conversation and the children spoke freely from their hearts.

The most striking result from the sessions was the lack of transparency for the visual information presented in the illustrations. As for the scientific level of our conversations, the pupils were seldom able to extract any new information from illustrations in the way it is clearly intended by textbook authors and teachers. Even though the illustrations might seem pedagogically well thought out it was repeatedly seen in the interviews that the pupils were unable to extract the central scientific information contained in the illustrations, on their own as well as in discussion with their peer.

As long as the information was well in accordance with previous knowledge they did not have problems. The pupils could all recall and discuss the function in the open versus closed circuit for instance. Common features in scientific illustrations, such as magnifications and cross-sections, were also easily understood. But at the point where visual information went beyond previous knowledge, and the scientific complexity increased, the pupils were instantly lost. In fact, most children did not seem to even trust the illustrations to contain information that was accessible to them. These children were reluctant to scrutinize the textbook pictures for any scientifically meaningful details. Even when specifically asked to search for information clearly presented in illustrations, many pupils failed to find it. They were either puzzled or used the illustrations to argue for an idea they already had, which several times were evident misconceptions. Hence, pupils were actually able to find support for their view in the illustrations even when the visual information was contradicting them.

Eric and Adam was one example of this. Throughout our discussion of electrical currents they were repeating the expression "from minus to plus", something they had probably heard in their education. They could also read it in the textbook, expressed in a subheading as "minus is drawn to plus". Furthermore, they found the battery illustration in the textbook to fit with this view; minus-sign in one end, plus-sign in the other and the electrons moving from one terminal to the other. It wasn't until Adam was explaining his own drawing (Fig. 1) that it became clear that they were not talking about electrons moving from the negative to the positive terminal, but instead both pupils were stating that it is the electrons that go from being negatively to positively charged.

Discussing an illustration of a closed circuit in the textbook:

Interviewer *"Why does the lamp go out then?"*

Eric *"Then it runs out on negative charges"*

Adam *"Then it's full of plus. Then the battery is empty"*

Eric (pointing to his drawing)
"Then out from this wire here and then it becomes plus charge. From minus to plus"

A little later, while discussing Adam's drawing:

Eric (pointing to the wire from the lamp to the positive terminal, where Adam has drawn minus signs)
"That should have been plus."

Adam	*"Yes, I know. I was taking a chance there. But it becomes plus anyway when they enter here" (pointing to the positive terminal on the battery)*

Fig 1. Adam's drawing of a battery

At this point the interviewer realized their view and asked why then that the electrons become positively charged. Eric and Adam speculated that it's because electrons "get to hot" or "get tired". Then followed a lengthy discussion with the interviewer pointing to details in several illustrations, and Eric and Adam arguing that if the electrons did not switch charge it would mean that the battery could "go on forever".

Eric and Adam were among the pupils that when requested to study the book glanced at the pictures only and did not incorporate the text. When asked why the bulb lights in a closed circuit it took them several minutes of studying the page and fanciful speculation before they realized there was a paragraph right in front of them with the heading "Why does the bulb light?".

The session with Eric and Adam was a typical example of pupils that had a functional, everyday understanding of electricity. They also made several connections to everyday experiences outside school and also to practical school activities. But just like many other pupils they did not use the textbook to collect any new theoretical information. The illustrations were indeed triggering a scientific discussion, both functional and more theoretically in-depth about the phenomena, but these children never once stopped to analyze the content of the pictures in relation to their previous knowledge. They were simply not used to doing that and the interviews were repeatedly showing this.

Another example of this was Selina. She was struggling to reconcile the concept of "around, around and around" which she brought with her to the interview session, with the idea of clashing currents. She had a notion of some sort of circularity included but she was at the same time convinced that the light comes from electrical charges from both terminals clashing in the glowing bulb.

Discussing an illustration of a closed circuit in the textbook:

Selina	*"Yes, they're coming from both sides there. They go around, around and around so it keeps on glowing."*

A little later, the interviewer is pressing on to find out what she means.

Interviewer	*"So, which way do they go?"*
Selina	*"From minus to plus… sort of."*
Interviewer	*"They go in one direction or both?"*

Selina *"They go both ways. I think."*

Her peer, Sandy, was mostly silent in this interview, sometimes nodding, pointing to a picture or repeating what Selina was stating. But at this point she suddenly takes courage, possibly strengthened by Selinas uncertainty.

Interviewer *"What does it look like in the picture? Look at the picture" (pointing to the textbook)*

Sandy *"No, they go from there." (Pointing to negative terminal) "And then they go around to plus" (her finger following the wire through the closed circuit)*

Here, Selina is quick to take command again.

Selina *"You can see it on the arrows here. I wasn't looking at the arrows, but if you do, you see they go from minus and they go around, around and around. Through this lamp then."*

The view of a complete circularity, in turn, is challenged in the last picture, the most complex illustration with a cross section of a battery. The illustration aims to put light on what happens inside the battery but none of the pupils were able to explain everything that the illustration was actually showing. This became obvious in their drawings of a battery. Most of these were certainly more similar to the textbook illustration than Adam's drawing (Fig. 1) was but still, even those who really tried to copy the textbook missed out on crucial details. They were also unable to explain the internal battery function. Hence, the gradient in scientific complexity among the illustrations coincided very well the pupils' inability to make meaning from them.

John and Lucy was an example of a pair pupils where both had a relatively solid view on the subject for this level. They were shy, a bit nervous but keen to deliver correct answers after some time of careful consideration. Interestingly, when they consulted the book for information they repeatedly searched in the text rather than the illustrations. And when they found what they were looking for they preferred to deliver answers as direct quotes. Illustrations could later be incorporated as support.

Discussing illustration of a cross-section of a battery:

Interviewer *"What do they want to show with this picture, you think?" (pointing to the textbook)*

John *(Studies the book opening for a few seconds)"That there is voltage across the terminals"*

This is a direct quote from the textbook, just under the illustration. It is presumably a "correct answer" but it is clear from the rest of the interview that these words do not mean anything to him. This focus on the text turned out to be a pattern for several pupils.

In this session Lucy also managed to read in undesired information form illustrations. One illustration shows four circuits and readers are asked which of the light bulbs that will light. This obviously forces the pupils to analyze the picture. The task was fairly simple for most pupils but Lucy surprisingly states that one of the closed circuits would not work. She was here comparing this illustration with two other on the same book opening.

Interviewer *"Why is that? Why does that one light and not that one?"*

Lucy *"Because these minus things come from the underside and there is a different metal there"(Pointing to where the wire is attached to the bulb)*

Lucy *"Yeah. You can see it here as well. (pointing to another illustration in the book.)*

What she had noted was actually that for all functional circuits with lit bulbs in the book the wire from the negative terminal was always attached to the bottom of the bulb and hence she concluded that this was required, which is not the case.

Overall there were some differences among the pupils in how they used the textbook, for instance some focused more on text, like John and Lucy, others on pictures like Eric and Adam. There was also a variation in previous knowledge and criticalness towards own level of scientific understanding. However, throughout all sessions the pupils, regardless of previous knowledge, did very seldom (on their own or with their peer) pick up any new scientific information in visual form from the illustrations. Illustrations in the textbook could inspire the children to discuss, to recall and to make connections to everyday experiences, but as for conveying scientific information they did not penetrate.

5. Conclusions

The textbook used here aims to explain basic as well as complex concepts in illustrations. Such pictures can stimulate discussions that are spot on the central scientific concepts but the results in this study show that illustrations in science school textbooks don't work on their own. Pupils that are not trained to interpret scientific models and illustrations need guidance to be able to grasp intended messages. Visual information is always coded and interpretation, the de-coding, is thus related to a particular context (Kress 2003). This influences how illustrations are understood by pupils and what may turn out to be problematic to them. Even when illustrations seem very obvious about what they are representing, individual pupils find different meanings and, left alone, they are unlikely to be helped at all by visual information.

Relating to Engebretsens (2012) discussion on cohesion and tension, the illustrations in the textbook portrayed a gradient in scientific complexity. The cross section of a battery clearly caused too much tension for the pupils at this level, at least for understanding all the included details. The open versus closed circuit on the other hand created very little tension. For other illustrations (and also the more basic features of the battery cross-section) one could expect there to be a balance between tension and cohesion and thereby an interesting area for learning. The fact that the illustrations still did not function in this respect could, theoretically, be related to a poor pedagogical design. However, the illustrations do look similar to many other illustrations of electricity in textbooks and there are no very obvious mistakes in them. Another possibility is that the content is out-dated, but this kind of batteries is still used in everyday situations and the scientific basics of electrical currents are unchanged over time. The conclusion instead is that pupils are not trained to interpret visual information by themselves and teachers and textbook authors overestimate their abilities to de-code this information in the same way an educated adult does. This conclusion is also supported by the advances that the pupils eventually made together with the interviewer in these sessions. In collaboration with the interviewer most of the children were able to pick out the central scientific message, they were also able to detect when and where the textbook was challenging their previous views.

References

Cook, M. P. (2006). Visual Representations in ScienceEducation: The Influence of Prior Knowledge and Cognitive Load Theory on Instructional Design Principles. *Science Education, 90*, 1073-1091.

Engebretsen, M. (2012). Balancing cohesion and tension in multimodal rhetoric. An interdisciplinary approach to the study of semiotic complexity. *Learning, Media and Technology, 37*, 145–162

Gilbert, J. (2005). *Visualization in Science Education*. Dordrecht: Springer.

Kress, G. R. (2003). *Literacy in the new media age*. London: Routledge.

Kress, G. & van Leeuwen, T. (1996). *Reading Images. The Grammar of Visual Design*. London: Routledge.

Lemke, J. (2000). Multimedia literacy demands of the scientific curriculum. *Linguistics and education, 10*, 247-271.

Martinec, R, & Salway, A. (2005). A system for image-text relations in new (and old) media. *Visual Communication, 4*, 337–71.

Pintó, R., & Ametller, J. (2002). Students' difficulties in reading images. *International Journal of Science Education, 24*, 333-341.

Vygotsky, L. S. 1978. *Mind in Society: The Development of Higher Psychological Processes*. Cambridge: Harvard University Press.

Wartofsky, M. W. 1979. *Models*. Dordrecht: Reidel.

Wu, H-K., Krajcik, J. S., & Soloway, E. 2001. Students' Use of a Visualization Tool in the Classroom. *Journal of Research in Science Teaching, 38*, 821-842.