Choosing the Proper Representation(s) in Physics

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Abstract. The representations used and produced by three undergraduate physics students discussing the physical concept of refraction were analyzed in terms of what roles the different representations were playing. Important contributions to the discussion were being made by speech, diagrams, mathematics and gestures. Although some redundancies between the representations were observed, they were to a great extent intertwined and reciprocally informing each other. The importance of practicing scientific communication is highlighted.

Keywords: Representations, physics, refraction, disciplinary discourse, discussion.

Introduction

Insight into the roles of representations in a disciplinary discourse (Airey & Linder, 2009) such as physics is an essential pedagogic appreciation. Our aim is to explore the roles that different representations play in the "agency of maker and remaker of messages" (Kress, 2010) in a physics discussion between undergraduate students. For this we draw on a social-semiotic perspective.

In the theoretical framework of social semiotics different representations have different affordances (Kress, Jewitt, Ogborn, & Tsatsarelis, 2001), meaning that different representations contribute in different proportions to a holistic, coherent picture of the topic at hand.

When communicating, the representation(s) that best 'fits' the intended message gets made (Kress et *al*., 2001; Kress, 2010). In analyzing communication, paying attention not only to the spoken or written words, but also to other modes of representation, may reveal the roles of the representation(s). We are viewing the discussion in terms of the representations used and produced by the students.

Method

In the pilot case study to be presented here, a group of three advanced undergraduate physics students were being asked to produce two explanations regarding the physical phenomenon of refraction, which is the bending of light when entering another medium (see *Figure 1*). One of the explanations was intended for a peer student who had forgotten about the phenomenon, and both were later being enacted by the researcher. A part of the discussion analysis is given in detail in Figure 2.

The students were being informed that they could use any equipment available in their explanation, which took place in a student physics laboratory. The students' discussion was video recorded and transcribed multimodally (Kress et al., 2001; Norris, 2004), meaning not only verbally but also in terms of other modes of representation, such as images and gestures etc.

The analysis was being done in terms of what representations the students used/produced in their discussion, in order to answer the question: What are the roles that the different representations play in this discussion? The relationships between the representations were analyzed through the construction of an analytical tool: a "thematic pattern" (Lemke, 1993).

Thematic patterns.

A thematic pattern (cf. Lemke, 1993) is a diagram showing thematic items (e.g., concepts) and what the meaning relations between them are. In this analysis a thematic pattern was being constructed out of the multimodal transcript, and thus extended to include entries not only from speech but also from other representational modes (e.g. visual and gestural). In an attempt to illustrate how this extended thematic pattern evolved dynamically we draw on the work by (Bloom, 2001) in showing the evolving discussion on a vertical timeline.

Results

At the time when the presented analysis of the students' discussion begins they had just finished drawing a ray diagram (see *Figure 1*) on the blackboard. Then the discussion referred to in *Figure 2* took place.

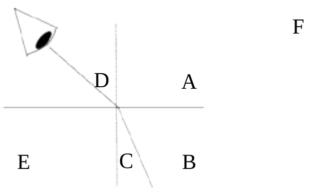

Figure 1. Diagram already drawn on the blackboard, showing a ray of light coming from below water, entering air and reaching the eye. Capital letters are positions referred to in *Figure 2*.

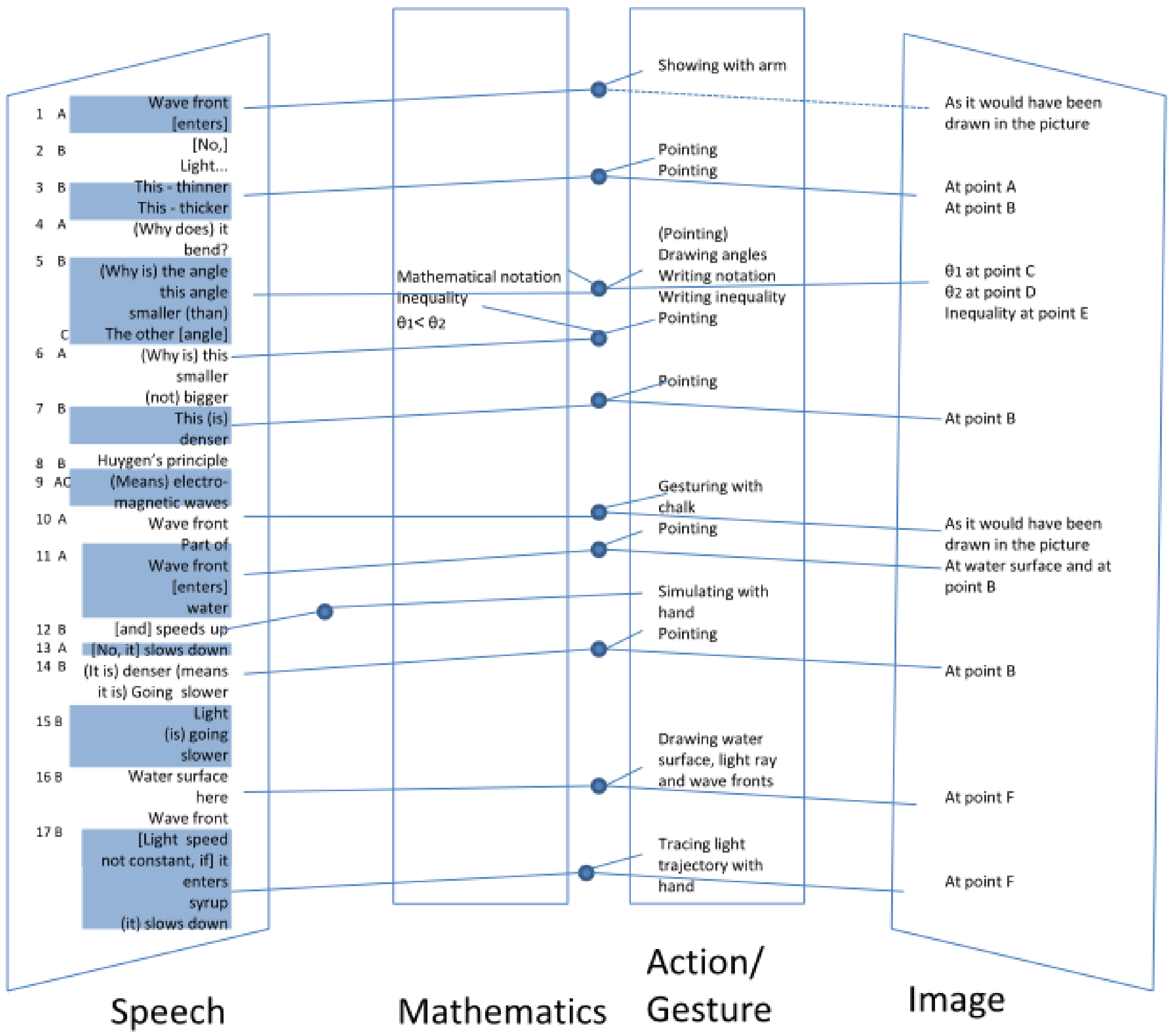

Figure 2. The dynamic development of the discussion. Points A-F are positions in *Figure 1*.

Discussion

Wave Fronts. The use of wave fronts[1] are suggested by student A. Despite being a canonical representation (i.e. used in most, or all, text books) the other students seem reluctant to use it until it has been properly motivated, and its explanatory power has been revealed. Important features of “wave fronts” may be appresented (Marton & Booth, 1997) (i.e. being experienced as a whole, despite many parts being invisible) to the person making the utterance, but may not be so for the listener.

Speech, Mathematics, Action/Gesture and Image. Eventually the spoken words ‘electromagnetic waves’ provide the key to the wave front as a viable means to explain refraction. Words often describe cause – consequence relationships; properties of things; and unfolding of events.

As a contrast to the motivation needed for the wave front diagram, the use of mathematics, such as θ (which is used by convention rather than being motivated) to stand for an angle, is not contested. The mathematics appears to be mostly redundant in the discussion, and its power may be obvious only later. However its statements are persistent through time, in contrast to gesture and speech.

Gesture is mostly used to point in the image, to make meaning in cooperation with, and to position spatially, what is being said in words. Occasionally it is used to simulate movement, and sometimes also to illustrate things before they are sufficiently agreed upon as to be drawn on the blackboard.

The image is a persistent sign, displayed and/or interacted with on the black board, as is the mathematics. It is a hub around, and with, which the other representations work. Images deal especially well with spatial and directional relationships.

Conclusion. The different representations are specialized, and the maker of a representation chooses the most apt one for doing the intended communicative work. That is why, in physics, any of all available representations may be used to complete a message, and in constant co-operation with other representations, rather than alone. “*Knowledge* is made and given shape in *representation* […]; the process of representation is identical to the shaping of knowledge. Makers of representations are shapers of knowledge. […] That is, knowledge is always *produced*, rather than *acquired*.” (Kress, 2010, p. 27) How to make different representations and how to relate them to each other are thus important goals in physics teaching and learning. Increasing the opportunities of practicing, rather than consuming, this co-operation of representations is of outmost importance in physics education.

References

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[1] An example of a wave front diagram: