WORKING WITH MAGNETIC FIELD TO LEARN ABOUT COORDINATE SYSTEMS: A SOCIAL SEMIOTIC APPROACH

Trevor S. Volkyn\textsuperscript{1,2}, John Airey\textsuperscript{1,3}, Bor Gregorcic\textsuperscript{1}, Filip Heijkenskjöld\textsuperscript{1}

\textsuperscript{1}Uppsala University, Uppsala, Sweden  
\textsuperscript{2}University of the Western Cape, South Africa  
\textsuperscript{3}Stockholm University, Stockholm, Sweden

In the teaching and learning of physics, a wide range of semiotic resources are used, such as spoken and written language, graphs, diagrams, mathematics, hands on work with apparatus, etc. (Lemke, 1998). In this respect it has been argued that there is a critical constellation of semiotic resources that is needed for appropriate construction of any given disciplinary concept (Airey & Linder, 2009; Airey, 2009). In this social semiotic tradition, it is the development of “fluency” in the individual semiotic resource systems and the ease of transduction (movement and coordination of meaning) between the various semiotic resource systems that makes disciplinary learning possible. We report here findings from an interpretive study of physics students working with a laboratory task designed to encourage transduction when learning about coordinate systems. A hand-held electronic measurement device (IOLab) was used to display components of the Earth’s magnetic field in real time. Our intention was for students to experience the movability of coordinate systems by open-ended investigation of dynamic, real-time changes in the x, y and z components displayed on the computer screen as they manipulated the device. Building on earlier work of Fredlund et. al. (2012) our analysis identifies three types of transduction, the last of which is transduction of meaning to a new modality (iconic gesture) not previously used by the students. We suggest this final form of transduction is indicative of what students have learned and offers the teacher a chance to confirm/challenge student conceptions. Our data clearly demonstrates how careful, open-ended task design, coupled with timely instructor questions can leverage the pedagogical affordances (Airey, 2015) of a range of semiotic resources to make physics learning possible. We therefore claim that understanding the roles that different semiotic resources play for physics learning is vital and call for further research in this area.

Keywords: physics, representations, teaching learning sequences

BACKGROUND

Theoretical framework

Meaning making in physics is necessarily distributed across a wide range of semiotic resources such as spoken and written language, algebra, graphs, diagrams, etc. (see for example McDermott, 1991; Lemke, 1998; Airey & Linder, 2009). Significantly, it has been argued that there is a critical constellation of semiotic resources that is necessary for understanding any given science concept (Airey, 2009). Further to this, Fredlund et. al. (2012) has shown how students can create such a critical constellation by using a persistent representation to coordinate other non-persistent semiotic resources, such as gesture and talk.

Coordinate systems and mediating tools

One of the most ubiquitous resources used in physics is the notion of coordinate systems. They appear to be fixed in textbooks; however, one of the main disciplinary affordances (Airey 2015; Fredlund et al. 2012) of coordinate systems is that they are movable. In this study our aim was for students to experience the movability of invisible invented coordinate systems by using a phenomenon that students cannot sense, magnetic field.

Many of the phenomena physics attempts to describe are not directly detectable with the human senses, e.g. magnetism. Mediating tools are then used to transduce the meaning potential (Bezemer & Kress, 2008; Kress, 2010) of the environment to a modality that is available to the senses, e.g. a compass. Transduction
moves meaning from one form to another, but in doing so, only certain aspects of the original information can be retained.

In this study we use a mediating tool, the IOLab which has high pedagogical affordance (Airey, 2015) for our purposes. The IOLab can be held in the hand and gives a real-time display of magnetic field on a computer screen. There is also a set of axes printed on the top and bottom faces of the device. See Selen (2013) for a presentation on the pedagogical uses for the IOLab.

**METHOD AND ANALYSIS**

This study involves an open-ended task presented in a Swedish upper secondary school. The advantages of open-ended tasks over closed ones are well reported in the literature (e.g. Roychoudhury & Roth, 1996). The students were simply asked to find the direction of Earth’s magnetic field with the IOLab device, and instructed to indicate this direction by sticking a red paper arrow onto any surface. Video footage was recorded of students working in pairs, using a video recorder. A complete multimodal transcription of the video data was completed (Baldry & Thibault, 2006). Since finding evidence of transduction was key to our analysis, the synchronicity of semiotic resource usage was carefully preserved in the transcription process.

**RESULTS**

After initial confusion, the students quickly started to manipulate the IOLab, leveraging their natural proprioception to “feel” the orientation of the device whilst actually looking at the screen. The combination of gaze and proprioception led the students to formulate a strategy to make either one or two components of the field zero (Figure 1.). In effect, the IOLab was rotated so that the zeroed coordinate axes are perpendicular to the field. Students then fixed the paper cut-out arrows to represent the direction of the magnetic field. Meaning was thus first transduced by the IOLab from the environment to the screen. This meaning was further transduced by the students to the red paper arrow. The arrow then functioned as a hub around which students could coordinate other resources and a critical constellation was then achieved. At this point expressions of insight and understanding were produced by the students. However, the data also revealed a new step in this multimodal sequence. The new meaning made discovered by the students was quickly transducted a third time, to a new semiotic resource, iconic gesture, hitherto not used by the students in the task. In Figure 2 the girl is using iconic gesture in her explanation, using the arrow as a coordinating hub – any axis perpendicular to the arrow would be zero.

![Figure 1. Range of semiotic resources used in task: gaze, graph, manipulation (proprioception), speech.](image1)

![Figure 2. Confirmatory transduction to iconic gesture with speech – “they would all be zero...90 degrees”. The arrow, a persistent representation, acts as a coordinating hub.](image2)
DISCUSSION AND CONCLUSION

Empirically, in their working with this open-ended task, students appeared to move seamlessly from an experience of simply holding an electronic device in their hands to an experience of holding a movable coordinate system. From their discussion it was also apparent that they gained insight into some properties of the Earth’s magnetic field. Here, the IOLab’s unique pedagogical affordances (real-time display and leveraging proprioception) seemed particularly apt for encouraging the necessary transduction to occur.

Theoretically, the data supports earlier findings that disciplinary meaning in physics activities is distributed across a range of semiotic resources and that students need a critical constellation of persistent and non-persistent resources to discern the meaning of new disciplinary content. The data also confirms the value of a fixed semiotic resource as a hub around which students can coordinate other resources (Fredlund, et.al. 2012). Here we advise that careful thought must go into what this coordinating semiotic resource should be.

One further recommendation is that teachers should be looking for coherent transduction to new previously unused semiotic resources. We suggest this final form of transduction is indicative of what students have learned and offers the teacher a chance to confirm/challenge student conceptions. Finally, we claim that understanding the roles that different semiotic resources play is vital for physics learning and call for further research in this area.

ACKNOWLEDGEMENTS

Support from the Swedish Research Council, VR project no. 2016-04113, is gratefully acknowledged.

REFERENCES


