Journal of Mathematical Behavior 25 (2006) 116–135
Mathematical Behavior
www.elsevier.com/locate/jmathb

"Then you can take half . . . almost" — Elementary students learning bar graphs and pie charts in a computer-based context

Lisbeth Åberg-Bengtsson *

Department of Education, Göteborg University, Box 300, SE 405 30 Göteborg, Sweden

Available online 5 April 2006

Abstract

Forty Swedish elementary students, 7–12 years of age and working in pairs, constructed a series of bar graphs and pie charts using a graphing application software as an instructional tool under the guidance of the researcher. After successive withdrawal of help, each pair drew a small number of graphic displays manually at the end of the data collection period. Evidence is provided that children's engagement with the graphing application software enhanced their understanding of essential graphical ideas and that even the youngest students appropriated and talked insightfully about a number of critical aspects of graphing. The students' gradual mastering of different aspects of graphing is argued to be movements within their "zones of proximal development" towards a more competent use of graphs.

Keywords: Graphicacy; Computer-based learning; Elementary students

The use of graphic representations as cultural artifacts for communicating, storing, or analyzing quantitative information is of relatively late date compared with, for example, using maps for navigation or the art of writing (see, e.g., Beniger & Robyn, 1978). During the latest centuries, these new forms of presenting data have, however, become indispensable tools in various contexts. According to Latour (1986), contemporary scientists, having transformed observations into such two-dimensional "inscriptions," "stop" looking at nature, economics, stars, etc. and start "seeing things" (see, also, Goodwin, 1994, 1997; Lynch, 1985). In modern society, however, information and data visualized in more or less advanced graphic formats are widespread, not only within scientific practices but also frequently occur in everyday life.

Being members of a graphicate[1] society, children of today seem to appropriate quite easily, and from an early age, some obvious aspects of graphing (e.g., Åberg-Bengtsson, 1998). However, to make sense of information presented graphically in a more elaborate and detailed way and more in line with conventions, more advanced modes of knowing are needed. The routes to full-fledged mastering and appropriation (Wertsch, 1998) of commonly used graphic representations may be long and troublesome. There are many examples in the literature of where important features of graphing are stumbling blocks for older as well as younger students (e.g., Åberg-Bengtsson, 1992, 1994, 1998; Goldberg & Andersson, 1989; Lindwall & Ivarsson, 2004).

* Tel.: +46 31 773 2378; fax: +46 31 773 2380.
E-mail address: lisbeth.aberg@ped.gu.se.

[1] *Graphicacy* is a term coined by Balchin and Coleman in 1966 for the ability to understand and communicate visual information, relationships, and ideas displayed in maps, graphs and charts of different types. The concept of graphicacy thus defined is described as a fourth basic skill separated from as well as complementary to literacy, numeracy, and articulacy, i.e., the abilities to read and write, calculate, and speak and listen respectively (related in Jackson, Berger, & Edwards, 1992). The corresponding adjective "graphicate" has been used by Åberg-Bengtsson (1998), Wainer (1980), among others.

0732-3123/$ – see front matter © 2006 Elsevier Inc. All rights reserved.
doi:10.1016/j.jmathb.2006.02.007

Making the students graphicate is an evident ambition in the Swedish national syllabuses for school mathematics. An articulated aim in compulsory education is that students should be able to understand and use basic statistical concepts as well as methods for collecting and processing data, including the description and comparison of important properties of statistical information. By the end of their fifth school year, young students are expected to be able to handle data in tables, graphs, and charts as well as use elementary coordinates.

It seems reasonable to assume that, at these early ages, the manual drawing of graphs and charts may be a laborious and even boring work for many children. Still, at the same time, one may also recognize that "hands on" activities is a preferable way of creating meaning and learning to handle cultural tools like this. It may be expected, though, that a computer-based learning environment for children of today may offer as good "hands on" exercises as manual drawing.

This article presents results from a research project with the overall aim of studying a small number of elementary students, some of which novices in *graphicacy*, learning to construct some types of commonly used graphs on the computer.

1. Some previous research

Students' understanding of and struggling with data presented graphically in, for example, graphs, charts, and cartograms have been approached by researchers advocating different research traditions, different methodologies, and different theoretical perspectives, some implications of which will be further addressed in the next section.

The focus of interest in a large body of investigations is directed either towards misunderstandings, misconceptions, difficulties, etc., or towards the assessment of performance when solving graphical problems or tests. For more than 20 years a number of difficulties that people may have with graphs have been well known and frequently returned to (see, e.g., Leinhardt, Zaslavsky, & Stein, 1990, for a review). This applies to, for example, the "height for slope confusion" (e.g., Preece, 1983; Roth, 2003), "iconic interpretations," that is to say mistakes due to the fallacy of reading a graph as a picture (e.g., Berg & Smith, 1994; Clement, 1989; Kerslake, 1981; Ottosson, 1987, 1988; see also Åberg-Bengtsson, 1994), or difficulties in seeing a curve as continuous (e.g., Åberg-Bengtsson, 1998; Kerslake, 1981). A considerable number of studies involve only older students at college or university level and advanced graphic representations (e.g., Goldberg & Anderson, 1989; Lindwall, 1998; Lindwall & Ivarsson, 2004).

Some researchers have been concerned with younger students' performance on graphicacy tests and/or on their solving of graphical problems. Wainer (1980), having administered a test including four different, common graphic formats to 360 U.S. students, concluded that, by fourth grade, the children appeared "to have on average reached a minimally acceptable level of adult graphicacy" (p. 337). Adopting a neo-Piagetian approach, Jones et al. (2000) hypothesized and identified four thinking levels for students in Grades 1 through 5. These levels, which were applied to statistical thinking across four constructs, represented what is called a "continuum from idiosyncratic to analytic reasoning" (p. 269). It was found that students in Grades 1 and 2 typically exhibited Level 1 and 2 thinking, whereas the older students reached higher levels. However, thinking over the four constructs was not stable for most students. Particularly, the construct "analyzing and interpreting data" seemed to lag behind.

In a research project carried out by Åberg-Bengtsson (1992, 1994) and Ottosson and Åberg-Bengtsson (1995), students from grades K-11 (i.e., 6–18 years of age) were interviewed about sets of graphs, charts, and cartograms. Thirty students participated in the pilot study, whereas the main study comprised 60 students. The results were presented as outcome spaces, in line with what is customary within the phenomenographic research approach (Marton, 1981), that is to say, hierarchies of qualitatively different ways of making sense of the graphs (Ottosson, 2000) were identified. With respect to the youngest students, it was found that they could "intuitively" understand a number of salient features, such as a larger sector or a taller column representing a greater frequency or amount of something (Åberg-Bengtsson, 1992, 1994). This immediate understanding seems related to what has been labeled "metaphoric resonance of the graph" by Ainley (2000). The most inclusive way of making sense of the information in the set of graphs, charts, and cartograms (which in the main study was composed of seven graphical representations) was, however, vaguely identified only in a few of the oldest students (Ottosson & Åberg-Bengtsson, 1995). A second project by Åberg-Bengtsson (1998) was directed only towards younger students, 7–10 years of age. Four different types of graphs were investigated, namely bar graphs, pie charts, pictorial charts, and line graphs. Two main strategies were found to be used for constructing and interpreting the graphs. For bar graphs, pie charts, and pictorial charts either a measuring or a counting strategy was adopted, whereas for line graphs a division line was identified between making use of the coordinates either as