The Role of graphs in IBL study of optical diffraction by secondary students

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Abstract. Graphs have a special role in physics and in physics education, but several research studies evidenced serious difficulties in reading, constructing and understanding graphs. On the base of a research educational path a study was conducted on the role of graph in learning optical diffraction of high school students.

1 Introduction

Graphs have a special role in physics and in physics education [1] not only for a synthetic data representation, but particularly because they give access to the "revelation of the complex" [2]. In spate of this, a wide literature related to many topics both in physics and other scientific disciplines evidenced the difficulties of students in reading, constructing or interpreting graphs [3-10]. On-line sensors offered new learning opportunities in that area of concern, aimed at constructing physics concepts and developing graphing competencies [11-13]. New strategies have been studied to change graphing obstacles in learning tools [14-16].

2 Research

Optical diffraction is the focus of a series of activities in an inquiry based laboratory oriented to bridge from classical to modern physics for secondary school students [17,18]. A research based educational path suggests a preliminary qualitative exploration of a diffraction pattern with the task to sketch the graph of light intensity vs position. The second step of the activity offers to the students the opportunity to measure intensity vs position by means of an USB computer on-line sensors system working as RTL. By means of tutorials, we studied the learning path in interpreting the diffraction phenomenon and the role of graphs of a sample of more than 200 Italian upper secondary students 17-18 years old. Students learning path were monitored using an open inquiry based tutorial, free notes of researchers during activities, students reports of their labwork. A) First, students explored qualitatively optical diffraction produced by single slits, just looking at the diffraction pattern produced by red-laser light diffracted by a single slit on a withe screen. They were requested to draw the image on the screen, describe it, draw the corresponding intensity distribution vs transversal position they expected to observe performing a quantitative experiment and to comment that graph. B) Then, students faced the role of parameters (D: distance slit-screen; a: slit width; λ: laser color used) in affecting the diffraction pattern observed on the screen. Presenting the opportunity to use Lucegrafo, an on-line system able to collect with a light sensor the intensity vs position [19], students were requested to design a project of quantitative experiment and then of data analysis to characterize quantitatively the diffraction distribution. C) Students in groups of 3-4 performed some experiments in lab and analyzed and elaborated data (usually being tutored by their school teacher).

3 Data Discussion and Conclusion

Analyzing first drawings (at the end of step A) it emerged that the majority of students tend to represent only the envelope of the intensity, disregarding the periodic change in the intensity distribution and in particular the presence of minima. This seems connected on one side to the absence of a coherent physical model capable to explain the presence of minima [20], on the other side to the lack in their mathematical background of complex functions such as the square $\sin^2$ describing a diffraction pattern. Another group of students showed the tendency to emphasize the presence of minima with discontinuous curves. This seems connected to an idea of a discontinuous distribution of the light intensity coherent with the students' pattern drawings. When asked to design an experiment, students tend to mix parameters (D-a-λ) and physical quantities (light intensity, position) to be collected. Performing the experiment and the analysis of on-line graphs the large majority of students gained a complete vision of the phenomenology, distinguishing the role of parameters and of the physical quantities measured. Few students continued to emphasize only the intensity of the central maximum in their distribution drawing, characterizing diffraction with an "enlargement of the pattern", because any new models were activated. In the analysis proposed by students it emerged that they feel the importance to analyze position of minima or maxima and their relative intensity. Usually they connected the minima position vs order number to the trivial minima condition. The intensity vs position relation constitutes an immediate goal only for few students. Sharing the suggestion of all the students of a class it was possible to reach satisfactory students' learning, without an instructional-guided path.

References

[1] C. Deacon, The importance of graphs in undergraduate physics, *The Physics Teacher,* 37 (1999) 270-274.

[2] E. R. Tufte, *The Visual Display of Quantitative Information,* Cheshire: Graphics Press., 2001.

[3] D.E. Trowbridge and L.C. McDermott, Investigation of student understanding of the concept of velocity in one dimension, *American Journal of Physics,* 48 (1980) 1020-1028.

[4] D.E., Trowbridge and L. C. McDermott, Investigation of student understanding of the concept of acceleration in one dimension, *American Journal of Physics*, 48 (1981) 242-253.

[5] J.M. Padilla, L.D. McKenzie & L.E. Shaw, An examination of line graphing ability of students in grades seven through twelve, *Scholl Science & Mathematics*, 86 (1986) 20–26.

[6] L.C. McDermott, M.L. Rosenquist, & E.H. van Zee, Student difficulties in connecting graphs and physics: Examples from kinematics, *American Journal of Physics*, 55 (1987) 503–513.

[7] R. Beichner, Testing student understanding of kinematics graphs, *A.J.P.*, 62 (1994) 750-762.

[8] P. Shah & J. Hoeffner, Review of graph comprehension research: Implications for instruction, *Educational Psychology Review*, 14 (2002) 47–69.

[9] N. Glazer, Challenges with graph interpretation: a review of the literature, *Studies in Science Education*, 47 (2) (2011) 183-210.

[10] M. Planinic, Ivanjek, L. A. Susac & Z. Milin-Sipus, Comparison of university students' understanding of graphs in different contexts, *Phys. Rev. ST Phys. Educ. Res.* 9 (2013) 020103.

[11] R.K. Thornton, and D.R. Sokoloff, Learning motion concepts using real-time microcomputer-based laboratory tools, *American Journal of Physics*, 58 (1990) 858-867.

[12] M.T.Svec, Effect of MBL on graphing interpretation skills and understanding of motion. *Paper presented at NARST*, San Francisco, CA. Retrived at: http://files.eric.ed.gov/fulltext/ED383551.pdf, 1995.

[13] M. Kozhevnikov, R. Thornton, Real-Time Data Display, Spatial Visualization Ability, and Learning Force and Motion Concepts, *Journal of Science Education and Technology*, 15 (1) (2006) 111-132.

[14] D.R. Sokoloff, P. W. Lawson, R. K. Thornton, *Real Time Physics*, New York: Wiley, 2004.

[15] J. E. Fan, Drawing to Learn: How Producing Graphical Representations Enhances Scientific Thinking, *Translational Issues in Psychological Science*, 1 (2) (2015) 170–181

[16] J. Woolnough, How can students learn to apply their mathematical knowledge to interpret graphs in physics?, *Research in Science Education, 30* (3) (2000) 259-268.

[17] F. Corni, V. Mascellani, E. Mazzega, M. Michelini, G. Ottaviani, *A simple on-line system employed in diffraction experiments, in Light and Information,* Girep book, L C Pereira, J A Ferreira, Eds, Univ. do Minho, Braga, 1993.

[18] L. Santi, E. Mazzega, M. Michelini Understand radiation Interference by means of computer modelling, *Light and Information,* L. C. Pereira, J A Ferreira Eds., Univ. do Minho, Braga 1993, pp. 372-380.

[19] M. Gervasio, M. Michelini, Lucegrafo. a simple USB Data Acquisition System for Diffraction, *Prooc. MPTL 14*, at http://www.fisica.uniud.it/URDF/mptl14/contents.htm, 2009.

[20] M. Michelini, L. Santi, A. Stefanel, Upper secondary students face optical diffraction, in E. Kajfasz, and R. Triay (eds), *Proc. FFP14,* http://pos.sissa.it/archive/conferences/224/240/FFP14_240.pdf. 2014.