Analysis of Media Graphs and Significant Sense

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Abstract -- This paper discusses aspects of interpretation of graphs including those related to the interface between different contexts of interpretation. Particularly it is discussed the notion of Critical Sense as a skill to analyse data its interrelations rather than simply accepting the initial impression given by the graph. We suggest that Critical Sense in graphing can help readers to balance several aspects involved interpretation of media graphs in certain contexts. This paper also presents initial findings from our analyses of study with student teachers interpreting media graphs. We are concerned to study Critical Sense in student teachers as a way of helping us, and them, think about teaching and learning graphing in ways that will support the development of Critical Sense.

I. INTERPRETATION OF GRAPHS

Friel, Curcio, and Bright (2001) stated that statistical graphs consist of four components: framework, specifiers, labels, and background, which are used to convey information in a variety of fields which use spatial characteristics (e.g. height or length) to represent quantity (e.g. the cost of living). The interpretation of statistical graphs might be viewed as a key element of the whole 'statistical investigation process' which comprises: posing the question, collecting data, analysing data, interpreting the results, making deductions and communicating results (Jones, Mooney, Langral, and Thorton, 2002; Friel, Bright and Curcio, 1997). Interpretation of graphs is a process by which people can establish relationships within data, and infer information (Shaughnessy, Garfield and Greer, 1996). Therefore, it is not only a unilateral visual perception (in which readers directly decode the information displayed in graphs through universal psych-physiological mechanisms) as some authors believe (e.g. Kosslyn, 1994). The interpretation of graphs is a complex process in which different aspects are involved (Gall, 2002; Friel et al., 2001). Consequently, for example, technical knowledge about the data handling stages and familiarity with components of graphs are not sufficient to ensure understanding of a particular graph (Monteiro, 2002).

Several studies have given evidence which supports the context dependence of the interpretation of graphs. For example, Gal (2002) proposes people can engage in different process of interpretation of graphs depending on the context in which the person is involved. Gal (2002) cited two main kinds of contexts in which the interpretation of graphs might be developed: 'enquiry' and 'reading'. In *enquiry* contexts (as suggested by Wild and Pfannkuch, 1999) the people act as 'data producers' and usually have to interpret their own data and report their findings (e.g. researchers and statisticians). The *reading* contexts emerge in everyday situations in which people see and interpret graphs (e.g. watching TV, reading newspaper, looking advertisements while shopping, visiting internet sites etc). Even though differentiated these two types of contexts, each context is not homogenously defined because people can develop different types of participation. For example, people engaged in a *reading* context can be actors, speakers, writers, readers, listeners, or viewers, in either passive or active roles. Gall (2002) also argues that the same person might be both a reader and/or a producer, depending on his/her engagement in certain context. In *reading* contexts media graphs are used to illustrate journalistic arguments and they might be used to emphasize and/or disguise aspects of data (Meira, 1997; Ainley, 2001). Therefore Gal (2002) suggests that *reading* contexts demand a certain level of 'statistical literacy' in which readers can interpret, critically evaluate, and comment on statistical information, arguments, and messages. The learning and teaching of graphing activities is also developed in *school* contexts (Monteiro & Ainley, 2003). The next subsection discusses particular characteristics which make them distinct from the two others cited.

II.INTERPRETATION OF GRAPHS IN SCHOOL CONTEXTS

Several countries which have included the teaching of interpretation of graphs as a curriculum topic in primary schools [e.g. England and Wales by National Curriculum (DES, 1989); and Brazil by Parâmetros Curriculares Nacionais (Brasil, 1997)]. Despite official inclusion, in some countries the teaching of graphing has been slow to develop (Shaughnessy et al., 1996). The reality in most *school* contexts is still associated with conventional classroom settings in which the teaching of graphing emphasises several sub-skills by a succession of tasks, such as scaling, drawing axes and plotting points (Ainley, 2000). Several studies have investigated aspects of the statistical literacy in interpretations of graphs in school contexts. Curcio (1987) and her colleagues (e.g. Friel, Bright and Curcio, 1997) were concerned about the design of assessment tasks that can detect students' difficulties in comprehension skills using statistical graphs. Curcio (1987) assessed fourth and seventh grade students' interpretations of traditional "school" graphs. From the analyses of students' responses, three types of interpretations were identified: *reading the data*, r*eading between the data*, and *reading beyond the data*.

However, the focus on typical pedagogical tasks seems to restrict the range of situations to which the interpretation of graphs is connected. In particular, Watson (1997) stated that statistical thinking need to be assessed as it occurs in social settings outside the classroom. She suggests that unusual and misleading graphs, which occur in print media, might be excellent examples to motivate and challenge students (Watson & Moritz, in press). Watson (1997) proposed a three-tiered hierarchy model for assessing statistical literacy based on authentic extracts from the media. Teachers might use these tiers to appreciate the increasingly complex nature of progression in the students' statistical thinking (Watson, 2000). Watson and Callingham (2003) have amplified the initial hierarchical schema, but continue to emphasise that the highest level of statistical thinking is associated with responses based on critical and questioning engagement with context.

In *school* contexts, teachers play a fundamental role in the construction of a teaching context for interpretation of graphs which should be meaningful and purposeful for participants (Ainley, Pratt, and Nardi, 2001). They should legitimise students' directions of enquiry, redirect their attention, encourage certain initiatives and discourage others; provoke meaning negotiation, maintain proper articulation of activities and conceptual matters (Ben-Zvi & Arcavi, 2001; Nemirovsky & Tierney, 2001; diSessa et al., 1991). Teachers need to guide the pedagogical setting towards situations in which statistically relevant aspects are discussed, such as questions related to the critical analysis of data or the necessity for the generation of new and useful information (Ainley, 2001; McClain & Cobb, 2001). The utilisation of media graphs in a school context (Watson, 1997) seems to be an interesting innovation, as it brings together two different contexts of graphing (the *school* context and the *reader* context). Nevertheless, Adler (2000) emphasises that the utilization of resources from out-of-school practices produces an important challenge for teachers, because the recontextualisation can be complicated and sometimes contradictory. That happens because the school graphing activities are not simply a continuation of solving mathematical problems outside school (Gal, 2002; Ainley, 2000; Evans & Rappaport, 1999; Adler, 2000).

These demanding aspects about the teaching of interpretation of graphs are complex and they are not been taught during conventional pre-services educational (Monteiro and Pinto, forthcoming; Cooney & Krainer, 1996). For example, Monteiro, Selva and Ferreira (2000) investigated the interpretation of graphs among Brazilian primary school teachers. The data analyses revealed that some of participants did know basic notions related to graphs. During the interview all teachers recognised the need to learn more about graphing. Most of them gave as reason for this situation the absence of specific studies in this topic during pre-service or in-service teaching education programs. In that particular study Monteiro et al. (2000) asked the teachers to interpret media graphs. The data analyses revealed that the process of interpretation mobilised knowledge and feelings which play important roles in the understanding of the data. For example, one of the graphs was about the incidence of different types of cancer cases among men and women between 1990 and 2020. Another one was about the duration of mammal animal gestations. The authors observed that the personal involvement of participants with the cancer topic seemed to be an important 'mobiliser' of the contexts of interviews. For example, when they were interpreting the cancer graph the teachers carried out different strategies to try to understand the data such as measurement of bars and conjectures about the causes of the figure variations displayed. In contrast, most of participant teachers approached the graph about gestation of mammals by describing the data shown. We believe that teacher education is a complex process that involves numerous specific variables such as multicultural diversity and the job market (Monteiro and Pinto, forthcoming). It would be simplistic to make general statements which emphasise only one factor, such as the assertion that previous experiences which teachers had in a specific knowledge area might directly effect their teaching approaches in that particular area (Becker & Selter, 1996). However, we acknowledge that a pre-service course which provides a wider range of opportunities for learning different aspects of mathematical content might support better teaching approaches for primary school teachers. For example, we believe experience in situations in which they can become aware of the complexity of aspects involved in the interpretation of media graphs. In particular, we suggest that the notion of Critical Sense (Monteiro and Ainley, 2002, 2003) might be an important skill which teachers can approach in *school* contexts for the interpretation of graphs.

Critical Sense in interpretation of media graphs

Monteiro and Ainley (2002, 2003) introduced the idea of Critical Sense as a skill to analyse data and its interrelations rather than simply accepting the initial impression given by the graph. We believe that Critical Sense in graphing is not an element or behaviour which can be acquired and applied for all situations. Critical Sense seems to be a context dependent skill, where 'context' may mean the "content" of the pedagogical task; or the "situation" in which the graph is interpreted. We see Critical Sense as an essential element of the kind of proficiency in graphing which is required for citizenship (e.g. Evans & Rappaport, 1999; Konold & Pollatsek, 2002). We wish to study Critical Sense in student teachers as a way of helping us, and them, think about teaching and learning graphing in ways that will support the development of Critical Sense. The term 'critical' has been used in educational fields as an important philosophical aspect, which is related to social, political, and economical issues involved in the educational process (e.g. Freire, 1972; Giroux, 1989). This perspective has also been developed by researchers who are concerned about mathematical education

(e.g. Skovsmose, 1994). Our approach to the interpretation of graphs as a particular aspect of the mathematical educational process converges on general ideas developed in those studies. Particularly, we would like to share some initial analyses of data collected from our study with student teachers.

III.EXPLORING THE NOTION OF CRITICAL SENSE

118 primary school student teachers took part in our study. A group was formed of 64 second-year students from an undergraduate education course at an English university. They were following three different specialisms: Mathematics, Science and English. Another group of participants was composed of 54 education post-graduate (PGCE) students. The study had three main stages. Initially, we gave a questionnaire to all student teachers just before they took a data handling section in a curriculum methods course in primary school mathematics. The questionnaire consisted of items that examined their familiarity with a *reader* contexts and their background in mathematics and statistics. It comprised two tasks based on print media graphs. Secondly, we made observations of the activities developed during the data handling section. Finally, a few months after the first and second stages, we interviewed some volunteers.

In this paper we will focus on the data related to the interviews about one graph (see Figure 1). This choice was taken because the data from the interviews give much clear evidence of the use of Critical Sense, which also emphasises our agreement with McKnight (1990) and Watson (2003) who remarked on the importance of this instrument, which enabled participants to express more details of graph interpretation. The graphs used as research tasks were chosen for three main reasons. Firstly, we anticipated that the topics associated with the graph were related to the interests of the students, most of them living and studying in or near Warwickshire. Secondly, the graphs seem to have accessible levels of complexity of mathematical relationships and concepts. Basically, the graphs present absolute and rational numbers, and percentages. Thirdly, we choose a graph, which might be straightforward to interpret. However, it was hard to find a media graph which we classified as totally "clear" and "easy" for interpretation. Therefore, we recognized that even in this straightforward graph, the way in which the target was represented might mislead the participants.

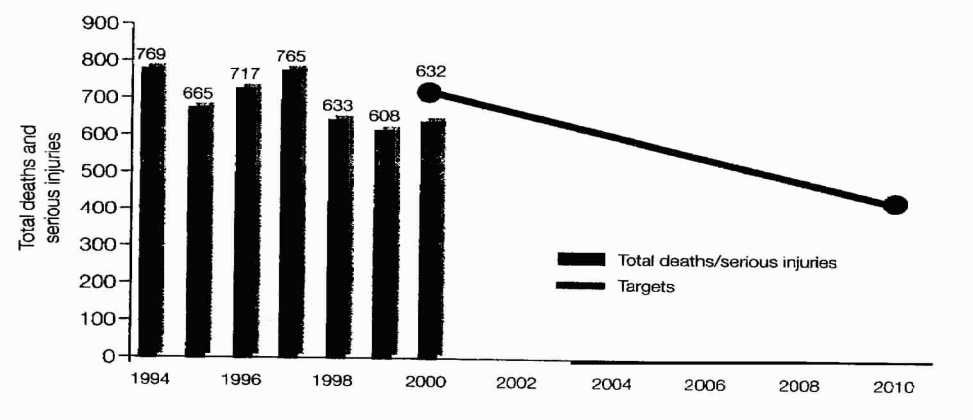

Figure 4: graphs reprinted from *Quality of life in Warwickshire*, September 2001, pp. 93-94.

We have asked student teachers to interpret media graphs which do not have noticeable "unusual" features, and which have a certain level of familiarity for the readers (i.e. participants' prior knowledge about topic, mathematical content, and graphical form, Curcio, 1987). An example of one of the graphs used in the interviews is given in Figure 4.We structured the main questions of the interview based on the typology of Curcio (1987): *reading the data, reading between the data,* and *reading beyond the data.* However, the context of interview, the graph topic chosen, and the formulation of questions (see below) seemed to suggest a different approach for the process of interpretation from that developed by Curcio (1987).

Reading the data questions: What is the total of number of deaths and serious injury per year? What is the lowest actual death and serious injury rate?

Reading between the data questions: Between 1994-1995, and 1997-1998, there was a decline in the number of deaths and serious injuries. Which period represents the greatest decline? Which years represent the highest and lowest number of deaths and serious injuries?

Reading beyond the data questions: What is your prediction for death rate and serious injury in 2001? If the targets for 2000-2010 were met, what do you think the pattern might be for 2010-2020?

The interviews were also learning opportunities for student teachers to think about their own interpretation of graphs, rather then an evaluation of the "capacities" and "difficulties" of interpretation. They could also reanalyse their previous questionnaire's answers, and discuss their expectation of teaching in graphing.

Student teachers interpreting media graphs

Even though the questions involving "reading the data" and "reading between the data" demanded direct answers, these questions provided an opportunity for the participants to carry out an initial exploration of the data. We also can infer that it is possible that the students could start to mobilise unspoken interpretations associated with opinions and feelings about the data displayed. On the other hand, we observed that when students were answering the "read beyond the data" questions they generated a wider and deeper exploration of data displayed on the graph. We will present some examples of interpretations produced which might help our discussion.

In the interview with Julia, a 19 year-old second-year student taking English specialism, we can observe she declared herself sceptical about the apparent tendency displayed.

R - "What is your prediction for death rate and serious injury in 2001?"
J - It could be anything, couldn't it? It's not going to go down. They put… the target is going down… so just because they stuck a pin in it and draw a line down it doesn't mean going down, does it? … [Observing]… It is probably going to be middling about the same, maybe… 615 something… just been fluctuating … It's gone down a bit there, like compare to those it seems going down a level a little bit …something like that… between 600 and 615 (…) [I am observing] the patterns… I don't think it is going necessarily going down.

Her answer seemed to be based on the pattern presented on graph, but she made a distinction between what the graph is representing, and what would a sensible answer with what she knew about the data. She developed the same type of approach when she was answering the following question.

R - If the targets from 2000 to 2010 were met, what do you think the pattern might be from 2010 to 2020?"
J - If the… like it really did that, the line going down… than I suppose… if that works and than they want to… just keeping going down for the next 10 years. It will be 200 or something maybe. If it really works, which it probably wouldn't? And than just the line kept going down like that… that will be the pattern. It will be 200. It is very nice, isn't it? It's quite luxury.

It seems that Julia considered the structure of the graph and the data displayed, but she definitely did not believe in the trend represented on the graph, and criticised the implicit intention of showing the rectilinear decrease of targets displayed.

In the interview with Max, a 19 year-old second-year student taking Maths specialism, we can also observe a similar approach to the aspects involved in the interpretation. Facing a question that did not have an "exact answer", he initially tried to observe any tendency from the data displayed. However, he emphasised that a possible tendency could not be the only factor predicting the answer mainly because his knowledge about the context does not support this reading.

R - "If the targets from 2000-2010 were met, what do you think the pattern might be for 2010-2020?"
M - Well, I mean, by the graph you would say it will go down again, but realistically I'd say… it would… [Getting slow voice and looking at the graph]… you know… it stays the same, because you can only go so low with… You know… stopping road accidents…I think is going to happen, so think about the context of that… I would say it's going to stay the same… like more it's going even off rather than carry on going down…
R - If I would ask some number. Can you guess?
M - [Analysing the graph] I mean they've got round about…what's that? 450… if carry on… I would assume that it's going to stay around there… for the next period… like 400, 500 that kind of area rather than carry down to 300... It's going to stay in like the 400 or 500 bracket.

It seems that his reasonable answer was based on the articulation of his knowledge about the structure of the graph but also about his opinion regarding the context in which he believes the graph is related to.

The following exchange is from the interview with Hillary, 35 year-old PGCE student with degree in Music.

R - "What's your prediction for death rate and serious injury in 2001?"
H - 2001? Right. Hum…Yeah… I would say… eh… It would be… I mean I know it is going up… I know it is going up a little bit there. I think it would be down again about … says 600.

At moment is going up at… Yeah I think it will reduce it…I am not really going by… the graph, the flow of the graph… I am just going by a gut feeling more than anything. You'd like to think that it's coming down.

In this part of the interview, the student teacher began by looking closely at the graph, noticing the upward trend over the last two years, but then responded in terms of her feelings about the issue of traffic accidents. The interviewer then encouraged her to try to specify a prediction.

R - So do you think it would be some… If you guess some number, some rate?
H - Yeah, again… I am not… it's very hard to say because… I'm thinking that it's… I am just thinking of… basically the media coverage on this type of thing… And… especially around Christmas time around… there is always a focus to control the number of accidents on the road, and I think this country… Well, I know this is Warwickshire, but I think this … the government does do… does make an effort … and obviously there are reductions. So I am basing my information on that, not just what the graph is telling me. But obviously going from last… Going from year 2000. And … yeah… hum… 600. I don't think there will a dramatic decline. But yeah... if I would say figure, say 600.

When asked for a "figure" she gave reasons for the limits of her answer, in terms of her knowledge about attempts to improve road safety. She tried to get a balance between the information displayed, her "feelings" and the social context in which the "figure" might be related. At the ending of her interpretation she gave a reasonable conclusion based on the different aspects that were involved in her reading.

After Hillary answered the questions, the interviewer invited her to reanalyse the answers produced months before. It was an opportunity in which she compared both situations of reading the graph. It was a moment in which she could make explicit a factor, which might be meaningful for her interpretation: she was actually involved in an accident.

R - You produced these questions at that time.
H - All right, that is interesting. [Laughs]
R - Do you comment this? …Just if you want to…
H - I have been involved in an accident myself … It wasn't a particular serious accident. But, …I can perhaps relate to this statistics more …I think. I can actually see what it's telling me.

We can infer from analyses that Hillary's motivations and wishes played a prominent role in her interpretation. The fact she cares about the road accidents, and that she was actually involved in one of them was an essential meaning of the graph for Hillary. For example, she was trying to see what she wished, even though criticising and recognising the limits of her interpretation. The analyses of the interviews with student teachers have provided evidences which support the notion of Critical Sense as important aspect of interpretation of graphs contexts. The analyses also made available elements for discussion of teaching in graphing. For example, it seems important carry out new studies which investigate the nature of interpretation of graphs developed for teachers as aspect which might influence their teaching approaches related to this curricular topic. These studies also can avoid the 'pedagogical prescriptions' which do not consider the density of factors involved in the interpretative processes such as the readings of media graphs.

IV.CONCLUSIONS

The notion of Critical Sense seems to be an important element which can help to mobilise and balance a range of factors that might present in certain context of interpretation of graphs. We believe that traditional pedagogic contexts, where the purposes of the tasks set and the activities undertaken in graphing are different from those which apply to out-of-school contexts, will be unlikely opportunities for the development of Critical Sense. Bringing media graphs into the classroom will not, in itself, create such opportunities if the tasks which are set remain narrowly-focussed pedagogic tasks. Cooper and Dunne (2000) have demonstrated the difficulties which children encounter in answering mathematical questions that are set in 'everyday' contexts. They identify this difficulty as arising from the need to understand how much attention should be paid to the contextual content of the task.

The interpretation of graphs is not just a technical procedure but it is an activity in which people can mobilise a wide range of knowledge, experiences and feelings. Teachers are challenged to develop teaching approaches in graphing which consider the complexity of the process of interpretation of statistical graphs. In particular, pre-service and in-service teacher education programmes might introduce the discussion about the proposition of pedagogical contexts in which there is opportunity for pupils to experience the need to make a choice about the balance of attention between the everyday and the mathematical aspects that is most appropriate for a particular purpose: in other words, to develop Critical Sense.

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