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A Case Study on Pre-service Teachers Students' Interaction with Graphical Artefacts

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A Case Study on Pre-service Teacher Students' Interaction with Graphical Artefacts

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Abstract

This study reports from a pre-service teacher's online learning and assessment activity on determining variability of two graphical artefacts. Using a critical-analytical perspective to data, the present study indicate that the prospective teachers surveyed showed awareness of relevant subject specific operators and methods; however, these seem not be well coordinated and were submerged in forms of expressions characterized by intuitive methods and everyday language. Significantly the prospective teachers seemed to substitute statistical and mathematical methods with explanatory metaphors which while providing room for deeper subject specific engagement were however, only used superficially. Their reliance on everyday forms of expression and visual perception is perceive as a factor that might have hampered their effective choice and application of relevant subject specific tools and forms of expression. This observation puts to task the role of informal methods in statistics education.

Keywords: Statistical literacy, graphical artefacts, variability, unalikeability, online teaching

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Un Estudio de Caso sobre la Interacción de Futuros Maestros con Artefactos Gráficos

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Resumen

Este estudio presenta un estudio sobre actividades online de formación y evaluación dirigidas a formación del profesorado, sobre la variabilidad de dos artefactos gráficos. Utilizando una perspectiva analítica crítica de los datos, el presente estudio indica que los futuros maestros muestran conciencia de operadores y métodos específicos. Sin embargo parece que no muestran una buena coordinación y aparecen sumergidos en expresiones caracterizadas por métodos intuitivos y lenguaje cotidiano. Parece que los futuros maestros sustituyeron los métodos estadísticos y matemáticos por metáforas explicativas, que a pesar de que daban espacio para una comprensión más profunda, acabaron usándose de manera superficial. Su confianza en formas de expresión cotidianas se percibe como un factor que puede haber dificultado una elección y aplicación de herramientas y formas de expresión efectivamente. Esta observación pone en entredicho el papel de los métodos informales en la educación estadística.

Palabras clave: alfabetización estadística, artefactos gráficos, variabilidad, improbabilidad, formación online

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There is no doubt that statistical artefacts (e.g. tables and graphs) are ubiquitous in our contemporary society (cf. Garfield & Ben-Zvi, 2007a; Watson & Moritz, 2001; Lowrie, Diezmann & Logan, 2011), hence it is imperative for citizenry at an early age to attain statistical literacy. Bakker (2004a) observes that students need early exposure to statistical data analysis consequently there is a need to support them in this process. The almost limitless access that individual have to digital technology is perceived as providing an optimal conditions for graphs and diagrams to be used as tools for presenting information; it is easier to insert a diagram on a document than use pencil and ruler to construct one (cf Lowrie, et al., 2011; Stern, Aprea & Ebner, 2003). Watson and Moritz (2001) point out that a glance at most newspaper provides diverse example of use or misuse of 'graphical representations' in society. It ought to be pointed out that; information presentation is but only one function of graphical representations (or graphical artefacts). Graphical artefacts can also be used as analytical tools, that is, tools for reasoning and transfer e.g. from one context or domain to another (Stern et al., 2003). It is noteworthy that from a disciplinary viewpoint, data presentation (e.g. through graphs, tables) is one of the processes of statistical problem solving. Statistical problem solving has four components; the initial inquiry, data collection, data analysis and the interpretation of results, in the data analysis component there is the selection of appropriate numerical and graphical methods as well as using these to analyze the data (Franklin, Kader, Mewborn, Moreno, Peck, Perry & Scheaffer, 2007).

In spite of the ubiquitous nature of statistical artefacts, research shows that statistics possess a serious cognitive challenge to many students (c.f. Bakker, 2004a; Garfield & Ben-Zvi, 2004). Thus, statistics education would benefit from research seeking to better understand how teachers think about statistical concepts. According to Shaughnessy (2007), given the sensitive nature of conducting research involving teachers, a good deal of what is known about how teachers think and reason about statistics tend to be in some ways anecdotal. Makar and Confrey (2004) observed that working towards influencing the reasoning of experienced teachers may be difficult since they consider themselves experts and may not admit that they do not know.

In the present study, the activity of prospective elementary teachers is investigated as they discuss a task comparing variability of two graphical artefacts in an online setting. The significance of comparing variability using graphical artefact is, as it was mentioned earlier partly informed by the important role that graphs e.g. pie-charts, bar, line and pictorial graphs play in our contemporary society and partly based on its role as a key feature of statistical literacy (cf. González, Espinel & Ainley 2011). In most cases graphs and diagrams are the most visible aspects of the statistics process and thus crucial for consumers of statistics. It is thus expected of teachers to possess such skills that allow the connection of statistical concepts with appropriate graphical artefacts as well as being able to determine such graphical artefacts that effectively highlight necessary aspects of data. The importance of these skills is highlighted in the work of Alacasi, et al. (2011) who emphasizes that it is important that teachers possess the knowledge needed for making appropriate choice of graph, since deficiency in this ability may hinder effective teaching. Similar sentiments were suggested by Friel, Curcio and Bright (2001) who described graphical sense as recognizing the utility function of a graph in relation to another on the basis of the tasks and the kind of data represented.

Literature Review

According to Franklin et al. (2007, p. 12) “The main purpose of statistical analysis is to give an accounting of the variability in the data.” Since data is normally presented in graphs and tables, it is expected that statistical literacy might include being able to account for variability as presented in graphical artefacts. Cooper and Shore (2010) contend that to be able to recognize and understand the ways that variability is manifested in different types of graphs is part of the ability to think statistically. They suggest that the ability to differentiate the underlying structures of different graph types, to identifying the type of data and on which axis it is plotted, is a necessary step for perceiving variability graphically. This implies that the ways through which students interact with graphical artefacts may be instrumental to the sense making process. delMas, Garfield and Ooms (2005) also made similar observations and contend that some students might interpret the histogram as a bar graph, they also found that there was a general difficulty for the students to coordinate more information from the graphics.

The widespread access and use of digital technology, access to software applications and interactive websites increases the possibility of creating and manipulating or transforming graphical artefacts resulting in the possibility of unearthing different patterns in the data and possible information on variability. According to Pfannkuch (2007), regardless of the kind of graphical product used in research that is, whether produced by hand or by using digital aids, there are difficulties in communicating and articulating the meaning of these statistical representations in classrooms. The difficulties associate with communicating statistics can partly be explained by the nature of statistics: a number of concepts though sharing the same terminology with everyday forms of expression may not necessarily share the same meaning. According to Loosen, Lionen and Lacante (1985), the wordings used in an intuitive approach to variability such as 'variation', 'spread', 'diversity', 'spread', 'heterogeneity', 'fluctuations' etc. are open to different interpretations. Regarding the use of everyday forms of expression, Biehler (1997) postulates that everyday language does not support statistical reasoning as well as it supports deterministic reasoning and that the limitation of everyday language in expressing complex quantitative relations is a problem that needs to be overcome in interpreting and verbally describing statistical graphs and tables. According to Kader and Perry (2007), intuitive concepts of variation might differ among students such that a teacher in a classroom situation may be talking about one concept of variation while the students are thinking about another. In particular they develop on Loosen et al. (1985) construct of unalikeabilitity, which is how often observations differ from one another contrasted with say, how they differ from the center or from each other which is variability (Perry & Kader, 2005). For purposes of didaktik [broadly taken as learning and instruction] and to emphasize the difference by way of mathematical formulae, the constructs are illustrated in the form of equations below: in the first case how the data differs from the center (mean) is given by the common formulae for standard deviation.

(1) $$\mathrm{sd} = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n}}$$

How the data differ from each other that is, the within data standard deviation is given by the equation by Gordon (1985) who suggested a 'democratic' definition of the standard deviation perceived as a free agent and not necessarily as displacement from the mean [as given by equation (2) below].

(2) $$\mathrm{sd}_{ij} = \sqrt{\frac{\sum_{i=1}^{n}\sum_{j=1}^{n}(x_i - x_j)^2}{n^2}}$$

As mentioned earlier the concept of unalikeability measures how data differs from each other and not so much by how much. Using a binary system, Kader and Perry (2007) quantified variability of categorical data such that data of similar magnitude or likeness are assigned score 0 while those that are not similar score 1. Thus developing a formulae for coefficient of variability [see equation (3) below]

(3) $$u = \frac{\sum_{i \neq j}^{n} c(x_i, x_j)}{n^2 - n} \qquad c(x_i, x_j) = \begin{cases} 1, & x_i \neq x_j \\ 0, & x_i = x_j \end{cases}$$

Granted the communication seem to be a problem in mathematics classrooms, it is the onus of the teacher to understand what the students are communicating since this may be of use in designing and redesign lectures to meet the students at their cognitive level or even enrich the teaching and learning process. The utility of everyday forms of expression in nurturing statistical perspective to data has been documented in literature (e.g. Bakker 2004b; Bakker & Gravemeijer 2004). In a study reported by Bakker and Gravemeijer (2004) it is appreciated that in spite of their deficiency in statistics vocabulary, the students in the study were able to display some acceptable statistics working methods. The students "...used informal words to describe density (crowded, empty, piled up, clumped, busy), spread (spread out, close together), and shape (hill, bump)" (ibid. pp. 149). Through the use of 'informal expressions' the impression is given that the students in this study had 'an aggregate' or a 'global' view to data an undertaking that is otherwise documented in research as problematic (see e.g. Bakker 2004b; Ben-Zvi & Arcavi, 2001; Konold et al. 2004). It is noteworthy that in some cases it seems as though the local or individualistic approach to data attributed to students may also be explained by the students ‘proximity’ or knowledge of the data a factor that may obscure ‘statistical analysis’. In a study by Konold et al. (2004) it is suggested that students perceived of graphs of data as collection of points and rather than attending to aggregate features such as how the values cluster and spread over their range the students described the data by locating themselves within the distribution.

From the study Konold et al. (2004), it is reasonable to posit that in statistical activities where students related attributes are a source of data, this proximity to data may serve as a blind spot in interaction with data and in particular with graphical artefacts. Research (cf. Alacasi et al. 2011) suggests that other factors such as encountering unfamiliar graphs, the presence of embedded mathematical and statistical operators and forms of expressions and need to employ these in the sense making process also my influence the quality of interaction with graphical artefacts. In a study by Alacasi, et al. (2011) it was observed that pre-service teachers shied away from selecting pie-charts as a representational medium because they did not want to deal with proportional calculations.

Critical-Analytical Approach

From the observations outlined in this section, it can be claimed that hidden in the communication problem in statistics mentioned earlier might be caused by having to deal with non familiar data contexts, and insufficient grasp of embedded statistical and mathematical tools and forms of expressions. The desired expectation from this learning and assessment activity was that the prospective teacher students would assume a ‘critical-analytical’ perspective to data as it appears in a graphical artefact: specifically the interrogation of the different facets of the statistical process and the communication of findings. A critical-analytical approach to data analysis is perceived as involving evaluation of the data representation system, active engagement with subject specific operators and forms of expression as a way of making sense of the data. Through the online discussion the field of interaction was extended thus providing more avenues to evaluate the student interaction with the graphical artefacts.

Pursuing a critical-analytical approach to data is in the present study perceived as resonating with a socio-cultural perspective to learning as well as statistical literacy. Within a socio-cultural paradigm the influence of social interaction and tools is perceived as integral in the learning process (cf. Daniels 2008; Dysthe 2003). For example, Daniels posits that Vygotskian perspective a distinction is made between psychological and other tools and that the psychological tools can be used to direct the mind and behaviour. Radford (2013) writing within the theory of objectification suggests that learning is about knowing and becoming. Thus, in the critical-analytical approach the focus is on knowing and becoming with a goal of fostering critical-analytical citizenry. A number of researchers (e.g. Gal 2002; Monteiro & Ainley 2007) have emphasized the importance of taking a critical stance as well as asking critical questions with regard to statistical literacy. In a previous research presentation, it was shown that students results on items containing graphical artefacts from PISA survey test would broadly be placed in two major groups: the first consisting of items considered as requiring identification approach [use of factors including visual dimension and elementary operators e.g. addition] and a second group consisting of items considered as requiring a critical-analytical approach [these were characterized by the use of 'advanced' subject specific operators and forms of expression as well as being able to justify the choice and use of these operators]. Thus, attempts to make sense of graphical artefacts based on initial impression without backing it up with time tested subject specific operator and forms of expression can be perceived as leaning towards an identification approach to data analysis. In this framework to data analysis, identification approach does not necessarily have to be inferior or superficial if it is founded on appropriate statistical tools and forms of expression. However, it is not uncommon for low level identification approach to be characterized by what is here considered as taking the easiest immediate option which may not necessarily be optimal.

Thus, from a research perspective, the questions guiding the study are:

- How do prospective teacher students use the statistical tools or operators at their disposal to make sense of the graphical artefacts?
- What is the nature and level of online conversation of the prospective teacher students while discussing the task on graphical artefacts?

The Design of the Research

The present article is a result of a series of short undergraduate level lectures taught by the authors. This was an on-campus 15 ECTS credit elective course for prospective elementary school teacher students' in the didaktik of mathematics [generally perceived as mathematics education]. The course syllabus included the topic strands algebra and equations, geometry, statistics and probability, functions (elementary linear functions), problem solving and teaching aids. The general focus of the course was didaktik as such the teaching goal was on the development of mathematics concepts with the aim of supporting the learning and teaching of mathematics at the elementary school rather than 'mathematical' teaching of topic strands. Generally this included a review of some of the basic concepts from the topic strands mentioned above as well looking at the challenges of teaching and learning these concepts. The lecture sessions were made up of a small group of prospective teachers (students) consisting of eleven female and two male students respectively. Two lectures were involved in the course with the authors being in charge of the topic strands geometry, statistics and probability.

Typical of the open nature of the Swedish curriculum for the compulsory school, where focus is on 'participatory goal fulfilment' this course was open to local interpretation and time allocation. Thus, as much as it was a 15 ECTS [European credit transfer system] course, imply 10 weeks of fulltime studies, the lectures were spread over a period of four months including lectures, seminars and teaching practice. The actual teacher lead sessions were allocated nine days; with one day for students lead seminar and examination. Each of the topic strands that the authors were in charge of were allocated four hours of teacher lead sessions with the rest of the time being for student-to-student interaction as well as for independent reflections. Some factors associated with the course such as time constraints in relation to workload as well as the limited mathematical background of the students did not allow for deep engagement with some of the statistical concepts. Also the study program policy was that lectures and other learning activities were not mandatory as long as they were not examinable.

The Lectures

The outline of the lectures was traditional in keeping with the notion of 'lecturing'. The topic strand statistics was based on descriptive statistics and included defining statistics and the statistics process, a recap on the measure of central tendency and a mention of measures of dispersion as well as data presentation including the merits and de-merits of some of the data presentation methods e.g. graphs and tables was done. Other aspects that formed the content of the lectures included examples on how to introduce basic statistical concepts in a teaching context as well as the identification of some of the problems areas documented in research. Specific to statistics and of relevance to the present study, some aspects of exploratory data analysis (EDA) methods were illustrated. In EDA, data is explored using graphical techniques where the focus is on meaningful investigation of data sets with multiple representations with little probability theory or inferential statistics (Bakker, 2004a; Prodromou & Pratt 2006). A data set was used to illustrate aspects of data analysis, the benefits and disadvantages of a histogram, stem-and-leaf diagram as well a boxplot including conversion within the diagrams. According to Duval (2008, p. 39) "there is no mathematical thinking without using semiotic representations to change them into other semiotic representations".

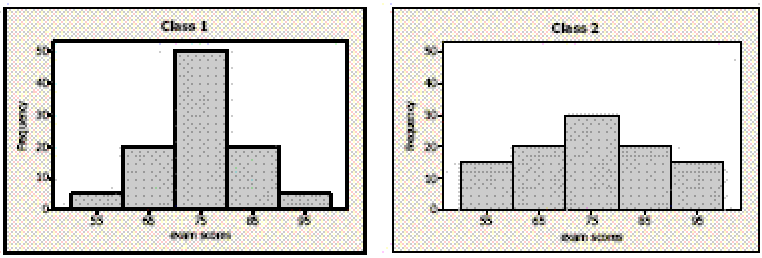
As it was mentioned earlier the outline of the lecture was basically traditional. Thus, to cater for some of the limitations of the teacher lead lectures and as a way of promoting the learning process, the open nature of the course was utilized. Since the students had access to an online resource; the First Class (henceforth denoted FC), a resource normally reserved for distance studies was incorporated even though this was an on-campus course. In utilizing the online resource the ambition was to as much as it is possible stimulate an explorative attitude towards learning, promote a critical and analytical stance, infuse creativity in learning and extend the interaction space among students. As a way of achieving these ambitions, at the end of the teacher lead session the students received three extensive tasks from the topic strands statistics and probability. These tasks were intended to provide the students with material that would also help them revise some of the concepts covered in the lectures. The students were randomly assigned to two online discussion groups. A condition imposed for the online discussions was that they were not to use audio or video conferencing, that is, the discussions were major written accounts. The choice to use this communication format that is, written discussion was influenced by a number of researchers (c.f. Borasi & Rose, 1989; Clarke, Waywood & Stephens, 1993; Emig, 1977) who suggest that writing down mathematics is a learning strategy that allows for in-depth understanding of mathematical concepts in question. According to Borasi and Rose (1989), restating concepts and rules in one's own words can facilitate student internalization since they are not just content to manipulate symbols successfully but strive to create their own meaning for symbols in order to express them in words on paper. This aspect is in the present study perceived as a fundamental element in the development of critical-analytical stance with regard to learning.

The Task

The task used in the present study involved comparing the variation of examination scores for two students classes presented in graphical artefacts of the type histogram; no actual data values were supplied. The students were to determine which on the two groups of students score had the largest variation. The task was deemed as appropriate as vehicle for promoting statistical literacy and 'statistical reasoning', where statistical reasoning is perceived as the way people 'reason' with statistical ideas and make sense of statistical concepts as well as being able to explain statistical processes (cf. Gal, 2002; Garfield, 2002; Garfield & Ben-Zvi, 2004). The task had the potential of bringing to fore the measures of central tendency and dispersion. While maintaining that measures of center are not the only way to characterize stable component of 'variable data', Konold and Pollatsek (2004) suggest that the measures of average and variability are inseparable. But then variation is also related to distribution, according to Bakker and Gravemejer (2004) without variation there is no distribution. The connectivity between variation and distribution is capture in the statement by Wild (2006) that "...the notion of 'distribution' is, at its most basic, intuitive level, 'the pattern of variation in a variable,' or set of variables in the multivariate case" (Wild, 2006, p. 11).

Since the data was presented in the form of a distribution graph, the histogram; the students' visual perception was a major factor in the problem solving process. The visual dimension is integral in interacting with graphical artefacts that is, data analysis. In the context of graphical artefacts the visual perceptions and context comes handy in making appropriate decision regarding the tools and operators that may be needed for further interaction with graphical artefacts. Given the nature of the task and the potential thereof [the task demanded a justification of the selected solution or a demonstration of its validity], it was expected that the 'appropriate' decisions would be characterized by general reasoning about centre in relation to spread as well as a thoughtful consideration to employ formal computation of the measures of centre and spread. This is considered as talking a critical-analytical approach to data and is an indication of sophisticated statistical thinking (cf. Groth, 2005). Since the students had been introduced to some of the concepts necessary in solving the task, it was expected of the students to take an approach emanating from a statistical stand point. The item dealt with the comparison of the variation of data set sharing mean, median and range [figure 1 below], the question was thus: Which alternative do you think is reasonable? Explain.

The following graphs show the distribution of exam scores in two classes.



Comparing the exam scores from the two classes, one could infer that
a) class 1 has a greater variability than class 2.
b) class 2 has a greater variability than class1.
c) class 1 and class 2 have equal variability.
Which alternative do you think is reasonable? Explain.

Figure 1. The assessment item: adapted from Cooper and Shore (2008).

Engaging the Task

Though the task was of the type multiple choice format, it is evident that a superficial approach to the data might not have been fruitful. The two data sets were such that they shared similar approximate of measures of centre as well as a basic measure of spread that is, the range. The range has also been referred to the simplest and crude measure of dispersion (see Gupta, 1992). The most visible difference was the shape of the graph, thus it was expected that the visual dimension would have a major influence in the students' forms of interaction with the graphical artefact. Bakker and Gravemeijer (2004) posit that reasoning with shapes forms the basis of reasoning about distributions. However, in the present study pointing out the difference in form or shape is not considered as sufficient since the task required the students to demonstrate that their preferred solution from among the three choices outlined in the task was the most viable [however, it is granted that discussion touching on tails of bell-shaped features of the histogram and the application of these in suggesting a solution for the task would be considered as application of subject specific operator and forms of expression] . For the task used in the present study, it was expected that the students would choose a graphical approach to illustrate their preferred choice, given the prominent role that data presentation through graphs etc took in the lectures. According to Ben-Zvi and Friedlander (1997, p. 50), "Choosing a representation from a variety of available options is a critical process in statistical analysis: An appropriate representation may reveal valuable patterns and trends in the data, supply answers to questions and help justify claims". In particular for the present study the production of a boxplot on the part of the students was highly desirable given its robustness in illustrating both centre and dispersion. Pfannkuch (2006) observes that boxplot was developed as a powerful method of summarizing distributions of data to allow visual comparisons of centre and spread through its depiction of the minimum and maximum values, the lower and upper quartile as well as the media (the five-number summary).

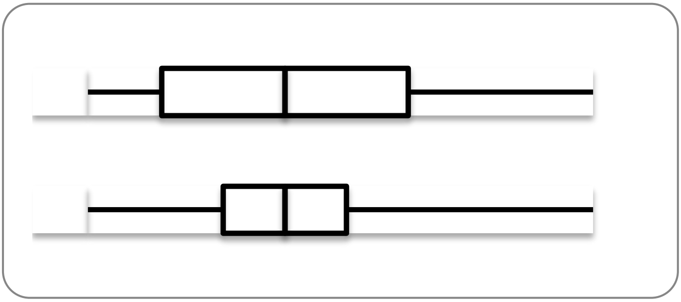


Figure 2. Showing the Boxplot of examination grade for the two classes

Another possible solution strategy for the students would have been an 'analytical approach'. The students had been briefly introduced to the construct mean absolute deviation, MAD. Given that the students had the liberty to consult other source including the tutor, a possibility of using the formula for computing standard deviation (eqn 1.) was not entirely unexpected. Given that the students attending the lectures did not have solid foundation in mathematics a purely analytical approach was not pursued during the lessons.

(4) $$\text{MAD} = \frac{1}{n}\sum_{i=1}^{n}|x_i - \bar{x}|$$

It is noteworthy that the solutions provided using the boxplot and MAD are approximates since the histogram does not provide us with raw data. Also with these conversions the qualities of the histogram as an indicator of the total data distribution is compromised in favour of highlighting specific features of the distribution.

Data Collection

The students were divided into two groups: from an official list that was arranged alphabetically, the students were systematically assigned numbers '1' or '2' in descending order. All the students assigned to number '1' were classified as group A while those assigned to number '2' were classified as group B. The same set of questions were then posted to each of the groups, these questions covered some important aspects from the topic strands from the lectures. Thus, there was a question on statistics, probability and an article reflecting on the teaching of statistics with emphasis on hands-on methods. The first two were such that they required some use of computation etc while the third was meant to solicit reflection on integrating everyday phenomenon of interest to students in teaching statistics. The exercise was to be conducted within a week's period. The online resource FC was made accessible only to members of each group for this period: at the end of the week access was denied and thus none of the students could make any more posts. After about a week, access was availed to all the groups. This was done to allow the students to make comparison on methods used to solve the task and then post comments or reflections.

Thus the data used in the present study comprises of students online posts as they explain their solution suggestions to the tasks. The language of instruction for the lessons and thus the discussion posts was Swedish. Care has been taken in the translation so as not to lose the dynamic and meaning of the discussion. It is noteworthy that some of the texts have been fine-tuned [without loss to the intended meaning] to make them more reader friendly as well as rendering them less revealing The records of conversations are recorded as they were posted i.e. in descending order with the last contribution at the end. In online discussions, time duration and threads are important indicators of engagement thus the entries are here recorded such that it is possible to scan the time duration between the threads, the title is also included, as a way of keeping truck of the threads. Since the students were discussing a number of different tasks, conversations on tasks not relevant to the present study have been edited out.

An important advantage of collecting data using online post is contained in the assumption that before making a post the student have reflected upon what they intend to put forward (communicate) so that it is a true reflection of what they understand or believe to be the correct solution to the task at hand. It is envisaged that the 'permanent' nature of the online post may engage students in instances of verifying the thoughts they hold before posting them, thus this could be a more reasonable way of capturing students knowing or understanding. Given that both the students and the lecturer were using this form of learning and assessment for the first time, it is expected there would be some kind of reservations on the part of the students to engage not to mention some 'administrative' and structural aspects that may prove to be a hindrance rather than promote the learning process e.g. technical problems attributed to the online resource. From a structural aspect the FC was the weakness that the posts are asynchronous which implies that earlier post maybe ignored and thus students may lose out on building on and comparing each other's reflections. As much as the desire was for students to provide written responses, the FC resource deprived the student of the ability to interact with (in) the graphical artefacts for example by making inscriptions online.

Results and Analysis

In this section the data is presented and analyzed using the critical-analytical framework mentioned in section 2.1. The data from the groups are presented and analysed separately since they seem to have adopted different approaches to solving the task.

Analysis of Online Log for Group A

The data collected from this group seem to indicate some awareness albeit feeble, of aspects of measures of dispersion on the part of the students. At the very beginning of the group discussion in Eva's [post number A2] mentions the two facets of variability viz., range and spread claiming that the range is the same for both histograms while the spread is larger for class11. She then proceeds in log A4 operationalize [define] them.

> [A4] 21/11 11:54 Re(2): the tasks - Eva
> Hello yes, I thought that in diagram 1 there were many in the middle of the range while those in diagram 2 were more evenly spread, but I think the range is the same for both [diagrams].

Eva's use of the range here is rather suspect given the expression which seems to imply that the range suspends the data rather than being an interval. The next log follows after two days when Helyn not only provide another explanation of the range but also brings in the expression "cognitive difference".

> [A5] 23/11 17:03 The tasks - Helny
> Hello! Eva and all members of this group!
> …
> The task on range.
> I interpret the task: the range extends from having 50 correct up to and including 95 correct and which is apparent for both graphs… that is the range is of the same size. Alternative c
> However, if one considers the number of students: "cognitive difference" then it is class two which has the largest variation. Based on [the observation] that every column [the tabular frequencies] contains an increasing number of students. Class 2 students have many 55 and 65 correct and 85/95 correct which implies that there is a large number of students at different cognitive level.
> (hence I agree with Eva)
> …
> Who are [the members of] in this group?
> Does someone have another suggestion?
> Helny

This form of expression though camouflaged in pedagogical terms is largely informal considered from a statistical perspective given that she is mostly likely making a comparison of between groups variability of the two graphical artefacts. In this log there seem to be a connection through comparison between visual and mathematical [number sense] aspects of engaging the task. Helny's contribution seems to go beyond providing a general announcement of the magnitude of observation but also makes a comparison between the bins.

At this point the group seem to be satisfied with the online contributions, such that an attempt by the tutor [the author] to engage them in trying out a conversion to a box plot is largely overlooked. The contribution by Karin in log A9 introduces the notion of 'distribution' and probability [chance]. This log is perceived as a modest attempt to organize the thoughts from the group members in more statistically correct forms of expression. Her explanation on probability seem to point towards an intuitive concept of variability unalikeability given her concern with how much individuals scores differ from each other (cf. Kader, 2007). However, her analysis of the distribution of the grades for the different classes reveals that this is an area that is not well founded on.

> [A9] 23/11 22:10 The variation task and lottery – Karin
> Variation task
> Concerning the task on variation I perceive that alternative b) is the correct answer. Just like Eva and Helny said, here the distribution of the results has been more dispersed in Class II. Since most of the students are at different levels. In Class I the probability is higher that if a student asks a classmate what their grades is, then it will be 75. The interesting thing with both diagrams is that the number of grades still is very evenly distributed. Like in Class I that there are exactly as many with 55 and 95, then 65 and 85 and the rest at 75. The same applies to Class II, that the numbers are exactly evenly distributed from middle score. Interesting…Then it would be alternative c) because the variation is then actually the same in both classes, since they are "evenly" distributed. Or? Shall I still point out that I am sticking to alternative b), since there is a slightly larger distribution anyway.

Karin contribution above can also be perceived as treating the bins as consisting of homogeneous scores. While this observation may be perceived as indicating a shaky grasp of histograms, in this case it is reasonable to accord her the benefit of doubt given that it is not uncommon to make this assumption in the case of converting to a boxplot. However, her attempts at providing an explanation using statistically correct forms of expression is not really successful thus he decides she is sticking to alternative b). Her uncertainty with mathematical/statistical explanations gradually drives her to seek for consensus that is solution by acclamation.

> [A13] 24/11 22:28 Re: the task - Karin
> Just as you point out on the task on variation of course it depends on how one perceives this thing, about how we view variation. Since we all interpret it in the same way, that the answer is b), so we are lucky that all interpret it in the same way. Although we are still discussing the issue of interpretation…yeah yeah, kind of confusing. What I want to highlight is that it is a question of [personal] interpretation as regard our perspective on variation. End of story.

The discussion log from this group shows that the entry point for solving the task was through elementary measures of variability ¨- the range. It was also evident that the students where more comfortable with informal forms of expression and where rather shy to engage in ‘advanced tools’ such as the boxplot in engaging the task. Thus, much as the group showed some awareness of some statistical concepts, they were not effective in using these tools and forms of expression to explain their suggested solution. A case in point is Eva who was not able to develop the use of boxplot though she seems to suggest the need of using statistical methods to bolster the solution. Much as the students did not use analytical methods nor entirely critical, it is evident that they interrogated the diagrams and were reflective in as far as the visual dimensions were concerned; they also attempted to ‘reach out’ to subject specific tools and operators but were however not fully confident to use them.

Analysis of Online Log for Group A

The activities of group B were majorly characterized by individual effort. There was some comparative delay in engaging in the tasks. However, after a few posts the group provided some interesting thoughts in there discussion. Similar to group A the entry point for the discussion centred on the range as observed in Linn’s log in B2 where she begins by referring to another task that was included for the online discussion.

> [B2] 21/11 16:11 graph of variation - Linn
> Well it would now be appropriate to get started with this one [meaning the task] then.
> I have not read that Danish article [referring to one of the other tasks] I cannot manage today. However, Johana and I looked at this one [task] on graph of variations earlier today.
> Quite spontaneously, we thought that option a) was most appropriate considering that there was such a big difference between those who scored 75 and the rest.
> But then one can of course consider the range [of the scores], of course it extends from 55-95 for the two classes. This could imply that it is alternative c) that is correct.

It seems the duo ‘spontaneously’ considered the visual aspects of the graph and where tempted to conclude that class I had the largest variability. However, being aware of the range as a measure of variability they settled for option c. Petra in B5 does not seem impressed by their suggested solution thus provides what can be considered as a ‘repair’ contribution in B4.

> [B4] 21/11 19:58 Re: graph of variation posted for Petra - Tutor
> Hello!
> I had a slightly different thought to yours, the way I see it, there is a larger variation in class II.
> It became easier when I thought of it as measuring different colours on students’ clothes in two classes. Then it is clear that there is a greater variation in Class II.
> Regards Petra

This solution seems to resonate with most of the group members being considered a ‘concrete or hands-on’. The explanation given by Petra seems to resonate with school practice where elementary school teachers normally have to keep a watch full eye during outdoor activities. This explanation may be seen as not just referring to within class differences but leaning more towards a most likely colour to be observed from the group of students [the intuitive notion of unalikeability]. Erik in B10 generally agrees with the group’s contribution but brings up an explanation that seems to involve the mean and which he considers are ‘logical’.

> [B10] 25/11 17:13 My reflections – Erik
> Hello all!
> …
> Diagrams:
> As regards the next task on the results of the two classes, I think even in this case it ought to be very logical that it is option B, that class II has a larger variation than class 1. This I explain by that the majority in class I have obtained an average score [it is not clear if he refers to the mean] while class II has a more spread and even score. There are more in class II with a higher and lower score which also entails there being greater variation.

> Now, I do not know if you have time to reflect on what I have posted since probably the online discussion group winds up soon. But if you can and have time to read through it and want to comment on and discuss, please feel free to send your views to my inbox here at FC.
> See you tomorrow in the student text lesson.
> With kind regards
> Erik

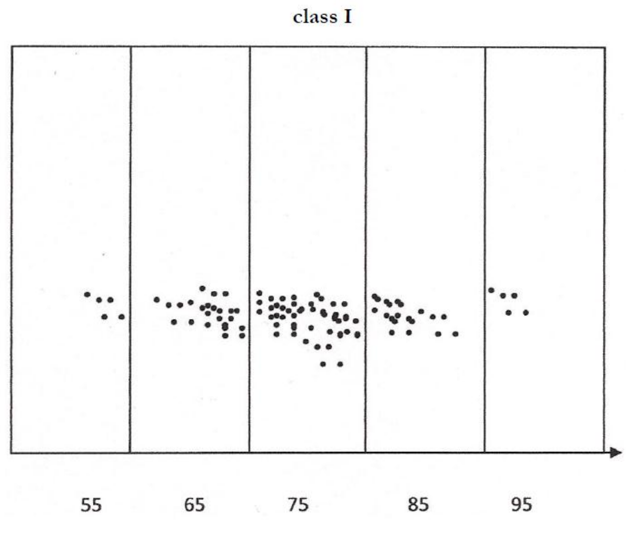
While it may not be clear if Erik in the above log is talking about the mean, the general impression is that he makes a connection between variability and a measure of centre. While the suggested solution might be perceived as devoid of precision in the application of subject specific forms of expression, it is comes closer to the standard approach to variability in statistics teaching and learning involving the mean. As if building on the thoughts provided by Erik, Charlotte in B12 provides a 'visual' connection between the mean and dispersion in her illustration of the shotgun and pellets. Her explanation may be perceived as showing an understanding on the concepts from an everyday perspective. In the case of Charlotte it seems the everyday forms of expression has an overhand in relation to statistical operators and forms of expression. Much as she appears weak in terms of analytical methods (statistical calculations) she however makes a plausible link as between variation seen as from a statistics perspective and

> [B12] 27/11 22:26 Now FINALLY I have embarked on this … anyone able to read? - Charlotte
> Hello!
> Sorry that I am so late with this work. *I am ashamed* I am in the processes of sequentially completing my assignments (I still have some piled up...) and now it is time for this [the online discussion].
> Since I have been away from mathematic s lessons, I received assistance from my (quite humorous) husband.
> Perhaps I have been too explicit in my explanation - but that is because it is too hard to just use text when one has to discuss these kinds of "problems"
> The attached document "The spread in the results" is about the task with the graphs. In the document I explain how I settled for alternative B as the most correct.

…
I hope that you are able to read this one now [referring to her post]… I am aware that I have tendency to be verbose…
Have a good time - now I'll have to do some abs
~*~ Charlotte ~*~
[NOTE: the explanation below was given as a separate attachment]

The spread in the results:

One way to discuss this is to perceive the results as pellet marks from a shotgun [aimed at] on a shooting target, where every student is assigned a pellet that hits within an area on the target. Then the tables could appear as follows:



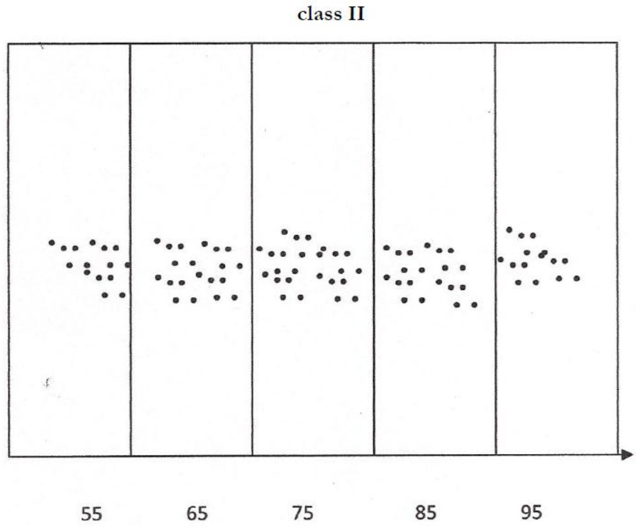


Figure 3. Charlotte's characterization of the variability of scores for the two classes

> Something that people talk about in connection with shotgun shots is the spread. This indicates how the pellets are scattered from the barrel. A narrow barrel means that one gets a little pellet spread and thus more pellets end up in the middle of the target. If one would liken the classes with a shot from a shotgun on a target then, it can be perceived that class II has a larger spread as more hits are further away from the centre of the target. If a similarity is made between variation and spread [of the pellets on the target board] then class II will have more variation than class I.

Discussion

The present study had a dual function first as an assessment and learning activity and secondly as an exploration of a group of prospective elementary school teacher students' interaction with graphical artefact in a specific statistical context. For these prospective teachers, this was probably the first time they were confronted with assessment and learning tasks online in the form presented here. From the records of the online conversations, it can be claimed that the prospective teachers took the exercise seriously [after an initial slow start especially for group B] and engaged in different ways of solving the tasks. Evidently there was no lack of creativity and explorative attitude as regards finding solutions for the problem. The format of the learning activity also provided feedback and insight into presenting some of the concepts covered in an organized learning situation.

From a critical-analytical perspective the prospective teachers were expected to apply relevant subject specific tools and forms of expression in interacting with the graphical artefacts presented in the tasks. However, the observation from the online post indicate that this was not the case as most of the arguments were grounded on ‘informal’ or everyday perspective to data while attempts to use subject specific tools and forms of expressions was characterized by what appeared as uncertainty. In some ways this finding confirms the assertion by Bakker (2004a) that students’ generally lack the conceptual understanding for analyzing data using the statistical techniques they have learnt. There were indications that the prospective teachers were aware of some of the statistical methods relevant for solving the tasks but they only made peripheral attempts to apply the same in justifying their suggested solutions. The subject specific tool that was explicitly mentioned was the range. This is not strange given that it is considered as the easiest to compute, requiring very little computation (Gupta, 1992). However, it is unreliable for comparing data sets with similar maximum and minimum values as was the case with the task at hand. In a number of cases the range seem to have been erroneously associated with the graphical artefact that is, the extent to which the x-axis suspends the data, thus indicating that the visual dimension of interaction with graphical artefacts was a dominant method for most students. Thus, the general activity of the prospective teachers may be perceived as an indication that they took an identification approach to data that is, relying on intuition, using non problematic tools and forms of expression etc.

Even though the prospective teachers’ interaction with the graphical artefacts could be characterized as identification approach, it is worth mentioning that they also displayed some level of reflective stance. However, this was very weak from a subject specific perspective partly because they seemed to treat the graphical artefacts (the histograms) as a self-sufficient source of information. That the prospective teachers were explaining the graphical artefacts is observed from the metaphors they used in their arguments. The prominent metaphors included treating the data as students with t-shirts of different colours and also perceiving the data as shotgun pellets on a target board. These metaphors probably served to're-individualize' the data to avoid dealing with its 'aggregate' nature. This is an interesting observation given that research (see e.g. Bakker, 2004b; Ben-Zvi & Arcavi, 2001; Konold, et al. 2004) indicates that students have problem with dealing with aggregate data. By're-individualizing' the data the prospective teachers are perceived as reclining to familiar methods and ways of interacting with graphical artefacts. Thus, it is viable to content that the metaphors also served to provide a visual alternative to the graphical artefacts. For example the diagram illustrating the shotgun and pellets on a target board provided a visual alternative for the histogram. In this instance the visual alternative had the advantage of relating variability with centre which was exemplified by the target. The metaphor of the t-shirts on the other hand points more to the concept of unalikeability-it is more likely to see say, red coloured t-shirt than a green coloured t-shirt. Significantly the metaphors served to reduce components of the graphical artefacts. According to delMas, Garfield and Ooms (2005) students have difficulties dealing with multiple aspects of graphical representations. Generally the metaphors illustrated some of the different ways students may perceive variability and thus provided possibilities for further discussions on the different facets of the construct of variability such as variation between and within observations.

Significant for these metaphors is that they are connected to the prospective teachers' everyday experience. Thus, may be perceived as a way of legitimizing an intuitive approach to the task. The everyday language used in relation to some of the metaphors may also be problematic from a subject specific perspective (see e.g. Loosen, Lionen & Lacante 1985). Whereas metaphors may provide powerful way of understanding statistical concepts, they at times suffered from the limitation of merely providing a local perspective to subject specific concepts and may not be used in a more general sense. The metaphor of the shotgun for example, provided a great illustration for variation in relation to the mean but may not necessarily be fruitful in illustrating data with different ranges and may instead promote erroneous view of the range taken as the length of the target board. It is noteworthy that as much as the prospective teachers probably found it easy to use 'informal' means in explaining their suggested solutions, there seem to have been a desire to connect their suggestions with subject specific forms of expression. In this regard it is observed that the prospective teachers reached out to what can be regarded as elementary subject specific tools and forms of expressions. For this task there was the use of subtraction in determining the range. Attempts to use other tools e.g. percent [which was otherwise not exactly a viable tool choice] and a mention of boxplot were not very successful in furthering arguments for the solutions suggested by the prospective teachers.

Thus, from the research questions perspective it was observed that in interaction with graphical artefact, the prospective teachers used in the first instance such subject specific tools that were within their conceptual reach but with everyday experience as point of departure. The need to operate within familiar grounds was perceived as leading them to reduce of aspects of the graphical artefact an observation that confirms research finding that students have difficulties dealing with multiple facets of graphical artefacts. The graphical artefact was presumably taken as self-sufficient as such the suggested solutions were largely attempts to narrate on the visual aspects of the graphical artefacts. Their conversation was consequently largely 'informal'. However, the informal nature of the prospective teachers may have been conditioned by their future career: they strived to provide explanations as a demonstration to enhance understanding as to pupils an aspect that was referred to as 'concretization'.

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