EXPLAINING TEACHERS' ATTITUDES TOWARDS STATISTICS

Assumpta Estrada[1] and Carmen Batanero [2]
[1]University of Lleida, [2]University of Granada, Spain
aestrada@matematica.udl.cat

We summarize three studies aimed at assessing teachers' attitudes towards statistics. In the first study the comparison of prospective and in-service primary school teachers' attitudes towards statistics revealed no differences. The second study explores the structure of pre-service teachers' attitudes towards statistics and its relationships with statistical knowledge. We finally present the preliminary results of an on-going study, where an open-ended questionnaire is used to find potential explanations for prospective teachers' positive or negative attitudes.

Teachers' training in statistics is generally focused on improving the cognitive aspects of instruction with relatively little attention paid to students' attitudes, feelings, beliefs or motivations. However, research has shown that anxious students tend to find the course more difficult than it should be and instructional goals more difficult to achieve (Mvududu, 2003) and that attitudes towards statistics might influence the students' statistical behaviour outside the classroom and their willingness to attend statistics courses in the future (Gal, Ginsburg & Schau, 1997). This is particularly relevant in educating teachers since an appropriate use of statistics would make them believe that statistics is useful in their students' professional and personal lives and that their students can be trained to understand and use statistics (Schau, 2003). Poor attitudes towards statistics in teachers might also be later transmitted to their own students when teaching the topic.

ATTITUDES TOWARDS STATISTICS

Theoretical and empirical issues related to attitudes have received much attention and different perspectives about what attitudes are have emerged over the years. In conceptualising the mathematics education affective domain, McLeod (1992) distinguished among emotions, attitudes and beliefs and conceptualised attitudes as learned predispositions to respond positively or negatively to given objects, situations, concepts, or persons. As such they possess cognitive (beliefs or knowledge), affective (emotional, motivational), and performance (behaviour or action tendencies) dimensions (Aiken, 1980, p. 2). More recently Phillip (2007) described attitudes as manners of acting, feeling or thinking that show a person's disposition or opinion and suggested that attitudes are more cognitive than emotions and change more slowly than they do. Attitudes may involve negative or positive feelings that result from positive or negative experiences over time in learning a topic (in this case statistics). Students may have had these experiences with statistics at school or in informal learning out of school or may transfer their feelings towards mathematics into statistics (Gal & Ginsburg, 1994).

Over the last two decades a large number of tools to measure attitudes and anxiety toward statistics have been developed (Gal & Ginsburg, 1994; Carmona, 2004). Three of the most widely used instruments to measure attitudes towards statistics are Wise's (1985) Attitudes Towards Statistics scale (ATS), Roberts and Saxe's (1982) Statistics Attitude Survey (SAS) and Schau, Stevents, Dauphine and del Vecchio's (1995) Survey of Attitudes Toward Statistics (SATS). While in the first part of our research we developed our own scale (Estrada, 2002), in the second and third studies we used Schau, Stevens, Dauphinee, & Del Vecchio' scale, where attitudes towards statistics are shown as a multidimensional construct, composed of four different analysable dimensions:

- Affect, with six items: Positive or negative feelings concerning statistics (e.g. I like statistics; I feel insecure when I have to do statistics problems).
- Cognitive competence with seven items: Perception of self-competence, knowledge and intellectual skills when applied to statistics (e.g., I can learn statistics, I make a lot of math errors in statistics).
- Value with nine items: Appreciation of the usefulness of statistics, relevance and value

 In C. Batanero, G. Burrill, C. Reading & A. Rossman (Eds.), *Joint ICMI/IASE Study: Teaching Statistics in School Mathematics. Challenges for Teaching and Teacher Education. Proceedings of the ICMI Study 18 and 2008 IASE Round Table Conference.*

of statistics in personal and professional life (e.g. Statistical skills will make me more employable; Statistics is worthless).

- Difficulty with six items: Perceived difficulty of statistics, as a subject (e.g. Statistics is a subject that is quickly learned by most people; Statistics is a complicated subject).

The interest in the beliefs, attitudes, and expectations that students bring into the statistics classrooms is increasing in statistics education, since "such factors can impede learning of statistics, or hinder the extent to which students will develop useful statistical intuitions and apply what they have learned outside the classroom" (Gal & Ginsburg, 1994, p. 1). Multidimensional studies of attitudes have been more frequent in recent years, and these seek to establish the basic elements that define them. Most studies report on small to moderate positive correlations between attitudes toward statistics and statistics achievement (e.g., Wise, 1985; Schau, Stevens, Dauphine & del Vecchio, 1995) in some cases using complex structural models (Wisenbaker, Scott & Nasser 1999; Schau, 2003, Nasser, 2004) or implicative analysis (Mastracci, 2000; Anastasiadou, 2005).

As regards teachers' attitudes, Nasser (2004) used SATS to examine the relationships between attitudes towards statistics, anxiety, mathematical aptitude and statistics achievement of 167 Arabic speaking pre-service teachers on an introductory statistics course. Teachers' achievement in statistics was assessed using ten open-ended questions related to descriptive statistics (frequency tables, measures of central tendency, measures of dispersion, types of distributions, and measures of association) and inferential statistics (basic concepts in inferential statistics, estimation, hypothesis testing, t-test, Chi-square test, and type I and II errors). In this study, however, no information was provided with regard to the specific misconceptions towards statistics in the teachers. Onwuegbuzie (1998; 2003) used ATS to compare pre-service teachers' attitudes toward statistics with that of graduate students enrolled in other courses and found that teachers in his sample had fewer positive attitudes towards statistics than graduate students of psychology and undergraduate students. Our research summarized below aims to complement information on teachers' attitudes towards statistics and consisted of three interrelated studies described below.

FIRST STUDY: COMPARING PROSPECTIVE AND IN-SERVICE TEACHERS' ATTITUDES TOWARDS STATISTICS

In the first stage of our study we compared the attitudes towards statistics of a sample of 66 in-service primary school teachers and another sample of 74 prospective primary school teachers. Attitudes were measured using a 25-item Likert scale that was developed for the research (Estrada, 2002); independent variables were gender, group (prospective vs in-service teachers), number of previous mathematics courses taken where some statistics was included, specialty (topic in which the prospective teachers were specializing or topic the teachers taught) and number of years of teaching experience in mathematics (for in-service teachers).

The results of the study showed moderate or positive attitudes towards statistics in both groups. We found a significant group effect in the Analysis of Variance, which favoured the prospective teachers group; that is, attitudes seemed to get worse with the actual practice of teaching. When analyzing the items in which there were significant differences by group, in-service teachers were more critical of the use of statistics in the media. Because they found statistics to be more useful for everyday life and gave it more value for the education of citizens, the prospective teachers tended to assume that they would include statistics in their teaching and found it easier to understand as well as more interesting than in-service teachers did. The number of previous mathematics courses with a statistics component taken had a significant effect, with attitudes improving as this number increased. There was no difference by gender and only a small difference regarding the specialty in which the pre-service teachers were majoring. In the case of in-service teachers we also found a significant result in terms of the number of years of teaching and a moderate negative correlation coefficient ($r=-0.37$), which suggests that attitudes get worse as teaching experience increases. The analysis of the specific items suggests that senior teachers had a greater tendency to suppress statistics when possible

and found statistics more difficult than younger teachers. Finally, our results also suggested that teachers that did not use statistics (or used it very little) in their professional lives (e.g., in assessment or to compare performances of different groups) tended to have poor attitudes towards statistics.

SECOND STUDY: RELATING PROSPECTIVE TEACHERS' ATTITUDES AND STATISTICAL KNOWLEDGE

Given that our main task is to train teachers, in the second and third studies we concentrated on prospective teachers. We were also interested in the pre-service teachers' specific misconceptions and difficulties in the elementary statistical concepts that they will teach in their future professional lives. In both studies participants were pre-service primary school teachers training at the Faculty of Education, Lérida, Spain (the average age of participants was 20.5 years). Most of them (80%) had studied descriptive statistics (graphs, frequency tables, averages, spread) and basic probability (simple and compound probability from a Laplacian approach) for about a month as part of mathematics in their own schooling. Only 10% had studied statistics any further (correlation, regression, total probability and the Bayes' theorem) in two or more previous mathematics courses at high school or university. All the participants were taking a mathematics education course where the statistics content is particularly sparse (about 10 teaching hours). The questionnaires were given within the mathematics education course before the statistics content was studied.

Participants in the second study totalled 367 prospective teachers. About 77% of the participants were female; this percentage reflects the real proportion of female students in Spanish Faculties of education. Student attitudes were measured using a Spanish translation of the Survey of Attitudes toward Statistics (SATS) (Schau, Stevens, Dauphinee & Del Vecchio, 1995). The reason for choosing this scale was that we wanted to analyse the structure of responses, and the reliability and validity of SATS have been assessed by different researchers (See Carmona, 2004). In the English version of SATS each item is given a seven-point response scale ranging from 1 (strongly disagree) to 7 (strongly agree). In our research, we used a scale ranging from 1 to 5. Before analysing the data, items with negative statements were recoded in such a way that the results could be directly compared. Reliability coefficients in our sample were Alpha = 0.89 for the total score, and Alpha = 0.80, 0.73, 0.77 and 0.7 for the affective, cognitive, value and difficulty factors, respectively. In Table 1 we present means, theoretical means (position of indifference) and *Z* scores for each component. *Z* scores were computed by subtracting empirical from theoretical means and dividing by the empirical standard deviation. By comparing these *Z* scores we see that prospective teachers in our sample had positive attitudes as in Onwuegbuzie's (1998) research. Cognitive competence had the highest score; so those teachers considered themselves to be able to learn statistics.

Table 1. Summary of results in total and component scores (N=367)

Component	Empirical Mean	Std Dev.	Max. Possible Score	Theoretical mean	*Z* score for mean
Affect	18.67	4.17	30	15	0.88
Cognitive	20.47	3.57	30	15	1.53
Value	29.60	5.03	45	25	0.91
Difficulty	20.33	3.32	35	17.5	0.85
Total	88.76	13.33	140	70	1.4

Knowledge of statistics was assessed using open-ended items taken from the *Statistical Reasoning Assessment* questionnaire, which is described in detail in Garfield (2003). Each item describes a statistics problem and offers several choices of responses. Different alternatives include a statement offering an explanation of the rationale for a particular choice. The particular SRA items used in this study assess understanding of the main statistics content in the Spanish primary school curriculum: reasoning about data, interpreting graphs, reasoning about average and spread, uncertainty and bias in sampling, and association. These items also evaluate

the possible existence of the following misconceptions or errors in reasoning: misconceptions involving averages, outcome approach, confusing correlation with causality, law of small numbers, and representativeness heuristics. Even when the difficulty was low or moderate in most SRA items, we found an important, and worrying, percentage in the sample of pre-service teachers that did not understand some of the elementary statistical concepts they will have to teach to their future students. For example 45% of participants did not take into account outliers when computing averages; 27.8% of them used the outcome approach; around 45% of them confused correlation with causality; 23.8% did not relate the mean to the total; more than 30% were insensitive to sample bias; 15% indicated that estimation was not possible because of random fluctuation; 30% did not understand the idea of cluster sampling; and around 30% made other errors related to sampling.

In Table 2 we present Pearson's correlation coefficients between the total score for the items taken from the SRA questionnaire and the attitudes total and component scores. The only non-significant component was difficulty, which suggests that participants' perception of the difficulty of statistics was unrelated to their statistical knowledge. Positive small correlations in the other components, although not significant, suggest that attitude and its components in general tend to improve a little with increased knowledge. In Table 3 we present the results of a variance analysis of the total score for the attitudes scale as regards different factors. The only significant factor was the number of courses with some statistics component previously taken by the participants (this number ranged between 0 and 3) in agreement with Onwuegbuzie's (2003) research with undergraduates, where the number of previous courses taken was also a significant factor. Our results also coincided with Anastasiadou (2005), who found no statistical difference between male and female students. Detailed analyses of scores showed that attitudes improved consistently with the number of courses. A summary of results was presented in Estrada, Batanero, Fortuny & Díaz (2005).

Table 2. Correlation coefficients with total score

Correlation with SRA score (* significant)	
Total score	0,23*
Affect	0,20*
Cognitive	0,26*
Difficulty	0,09
Value	0,22*

Table 3. Effect of factors on Attitudes

Source	d.f.	F	P value
Courses taken	1	10,10	0
Gender	1	3,26	0,07
Specialty	5	1,84	0,11
Interaction	5	0,60	0,7

THIRD STUDY: EXPLAINING TEACHERS' ATTITUDES TOWARDS STATISTICS

In order to understand the pre-service teachers' attitudes and misconceptions better, we carried out a complementary study of a new sample of prospective teachers (n=121) who were only given the 10 SATS items with lower scores in the second study and were asked to first complete these items and then justify their responses to the same. The students' characteristics are similar to those taking part in the second study and the average score and standard deviation for each item included in the third study was very similar to those obtained for the same item in the second study.

A qualitative analysis of open justifications for each item response served to classify the main reasons for positive and negative scorings in the third study. The main explanations given for positive attitudes were as follows: a) Considering statistics as an easy topic: "pretty logical and simple", "is the easiest part (of mathematics)"; b) Satisfactory learning experiences: "the teacher explained it well", "it was an interesting topic"; c) Novelty of the topic "I like topics that are non routine"; d) Perception of the usefulness of statistics for a teacher: "you have to know about statistics to be able to teach it to children", "it's useful for studying the students' achievement"; or its formative value: "essential in many different kinds of work", "useful in decision making". The main reasons for negative scoring appeared in the following categories: a) Lack of previous knowledge or training: "I only studied statistics at primary school and I hardly remember anything", "I never studied this topic"; b) Difficulty with statistical reasoning

"you cannot apply a mechanical procedure", "you need too much logical thinking"; c) Too formal teaching: "symbols and equations are too strange", " too abstract"; d) Considering that statistics is not valued in society "statistical knowledge is not required when you look for a job"; e) Lack of knowledge of applications: "I do not use statistics because I do not know where", "I found no possible applications of statistics". In summary, positive attitudes increase when students perceive the topic as easy, have good learning experiences and perceive value for their own professional work or for the students' education. Negative attitudes are linked to perceived difficulty, lack of knowledge and overly formal learning experiences.

Table 4. Item means and standard deviations in the two samples (Studies 2 and 3)

Component		N=387		N=121	
	Item statement	$\bar{x}$	s	$\bar{x}$	s
Affect	1.I feel insecure when I have to do statistics problems.	2.86	1.02	2.70	1.01
Cognitive	2. Statistics formulas are easy to understand.	2.95	1.00	2.83	1.03
Difficulty	3. Statistics is a complicated subject	2.87	1.02	2.90	1,05
Value	4. Statistics should be a required part of my professional training	2.79	0.97	2.80	1.01
Value	5. Statistical skills will make me more employable.	2.70	0.94	2.75	0.96
Value	6. I use statistics in my everyday life.	2.78	1.07	2.76	0.97
Affect	7. I enjoy taking statistics courses.	2.81	0.95	2.85	1.00
Difficulty	8. Statistics is a subject that is learned quickly by most people.	2.58	0.86	2.50	0.81
Difficulty	9. Statistics involves massive computation.	2.55	0.91	2.58	0.89
Difficulty	10. Statistics is highly technical.	2.84	0.86	2.63	0.90

CONCLUSIONS

Despite the limited possibilities of the generalization of these studies, due to the contextual and curricular specificity of the Spanish system for training teachers and non-random character of the sample we can draw some conclusions and implications for the training of teachers. First, it is reasonable to conclude that there might be a problem in Spain as regards teachers' statistical knowledge and attitudes that may have an impact on their own teaching of statistics and be a potential problem in implementing new curricular orientations that suggest teaching more statistics in Spanish primary schools. Our research also suggested that a main influence on teachers' attitudes is their previous knowledge of statistics as well as good learning experiences (non-abstract, with examples of applications in everyday and professional life).

Since attitudes towards statistics play a key role in predicting statistics achievement (Onwuegbuzie, 2003), teachers' educators are responsible for creating an emotionally and cognitively supportive environment in statistics training, where prospective teachers explore different statistical methods, gaining confidence in their own ability to learn and teach statistics and learning to value the role of statistics in modern society. Finally, we draw attention to the need to find more methods to convince both teacher trainers and prospective teachers that statistics is valuable and that basic statistics can be taught in an attractive and easy way. The first step in achieving these aims is to continue with research aimed at describing teachers' attitudes toward statistics and finding possible explanatory variables.

ACKNOWLEDGEMENT

Research supported by the project: SEJ2007-60110/EDUC. MCYT-FEDER.

REFERENCES

Aiken, L. R. (1980). Attitudes measurement research. In D. A. Payne (Ed.), *Recent developments in affective measurement* (pp. 1-24). San Francisco: Jossey-Bass.

Anastasiadou, S. (2005). Affective reactions and attitudes of the last class of Greek high school

students towards statistics. In M. Bosch (Ed.), *Proceedings of CERME IV. European Research in Mathematics Education.* [CD-ROM]. Sant Feliu de Guissols: ERME.

Carmona, J. (2004). Una revisión de las evidencias de fiabilidad y validez de los cuestionarios de actitudes y ansiedad hacia la estadística (Revising the realiability and validity evidence of attitudes and anxiety towards statistics questionnaires). *Statistics Education Research Journal, 3*(1), 5-28. Online: www.stat.auckland.ac.nz/~iase/serj/.

Estrada, A. (2002). *Análisis de las actitudes y conocimientos estadísticos elementales en la formación del profesorado* (Analysis of attitudes and elementary statistical knowledge in educating the teachers). Unpublished Ph.D. Universidad Autónoma de Barcelona.

Estrada, A., Batanero, C., Fortuny, J. M. & Diaz, M. C. (2005). A structural study of future teachers' attitudes towards statistics. In M. Bosch (Ed.), *Proceedings of CERME IV. European Research in Mathematics Education.* [CD-ROM]. Sant Feliu de Guissols: ERME.

Gal, I. & Ginsburg, L. (1994). The role of beliefs and attitudes in learning statistics: Towards an assessment framework. *Journal of Statistics Education, 2*(2). Online: www.amstat.org/publications/jse/.

Gal, I., Ginsburg, L., & Garfield, J. B. (1997). Monitoring attitudes and beliefs in statistics education. In I. Gal & J. B. Garfield (Eds.), *The assessment challenge in statistics education* (pp. 37-51). IOS, Press, Voorburg.

Garfield, J. B. (2003). Assessing statistical reasoning. *Statistics Education Research Journal, 2*(1), 22-38. Online: www.stat.auckland.ac.nz/~iase/serj/.

Mastracci, M. (2000). *Gli aspecti emotive nell'evolution dell'apprendimento della statistica e della sua valutazione. Un caso di studio sugli studenti di SSA* (The emotional aspects of learning statistics and its evaluation. A case study with SSA students). Tesis de Laurea. Universidad La Sapienza de Roma.

Mc Leod, D. B. (1992). Research on affect in mathematics education: A reconceptualization. In D. A. Grows (Eds.), *Handbook of Research on Mathematics Teaching and Learning* (pp. 575-596). Macmillam N.C.T.M.: New York.

Mvududu, N. (2003). A cross-cultural study of the connection between students' attitudes toward statistics and the use of constructivist strategies in the course. *Journal of Statistics Education, 11*(3). Online: www.amstat.org/publications/jse/.

Nasser, F. M. (2004). Structural model of the effects of cognitive and affective factors on the achievement of arabic-speaking pre-service teachers in introductory statistics. *Journal of Statistics Education, 12*(1). Online: www.amstat.org/publications/jse/.

Onwuegbuzie, A. J. (1998). Teachers' attitudes toward statistics. *Psychological Reports,* 83,1008-1010.

Onwuegbuzie, A.J. (2003). Modelling statistics achievement among graduate students. *Educational and Psychological Measurement, 63*(6), 1020-1038.

Phillipp, R. A. (2007). Mathematics teachers' beliefs and affects. In F. Lester (Ed.). *Second handbook of research on mathematics teaching and learning* (pp. 257-315). Charlotte, NC: Information Age Publishing and National Council of Teachers of Mathematics.

Roberts, D. M. & Saxe, J. E. (1982). Validity of a statistics attitude survey: A follow-up study. *Educational and Psychological Measurement, 42*, 907-912.

Schau, C. (2003). Students' attitudes: the other important outcome in statistics education. Paper presented at the *Joint Statistical Meeting*, San Francisco, CA, 2003.

Schau, C., Stevens, J., Dauphine, T., & del Vecchio, A. (1995). The development and validation of the survey of attitudes towards statistics. *Educational and Psychological Measurement, 55*(5), 868-875.

Wise, S. L. (1985). The development and validation of a scale measuring attitudes toward statistics. *Educational and Psychological Measurement, 45*, 401-405.

Wisenbaker, J., Scott, J. S., & Nasser, F. (1999). A cross-cultural comparison of path models relating attitudes about and achievement in Introductory Statistics Courses. Paper presented in the *52nd Session of the International Statistical Institute*, Helsinki. Online: www.stat.fi/isi99/proceedings.