TRAINING FUTURE RESEARCHERS IN STATISTICS EDUCATION: REFLECTIONS FROM THE SPANISH EXPERIENCE ®

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A main point to assure the future of statistics education research is the training of researchers through the Master's and Doctoral Programmes. Since in the majority of countries there are no specific departments of Statistics Education, this training is carried out from Mathematics Education, Statistics, Education, Psychology and other related departments, and even there starting a line of research in statistics education is not an easy task, due to the lack of trained supervisors, specific bibliography and funds. In this presentation I will describe the experience of starting the first Doctoral Programme in Mathematics Education at the University of Granada, and developing there a research group in statistics education. The contents of the Doctoral Programme will be analysed as a first step to establish what an ideal programme for training future researchers in statistics education would be.

TRAINING OF RESEARCHERS IN STATISTICS EDUCATION

One main goal of the IASE is to promote research related to teaching and learning statistics. As described in Jolliffe (1998), we still need to achieve academic recognition in the different disciplines or programmes where we work. In Batanero, Garfield, Ottaviani, and Truran (2000) and following discussion a group of researchers in Statistics Education reflected on their views about what research is and about the main research questions that statistics education research should address in the forthcoming years. In that paper we recognised that there is a considerable amount of experience in the world about conducting research into statistical education. We also suggested that we may now be at a stage where it would be possible to develop some general principles about what background knowledge we need in order to conduct quality research in statistical education and about how might we best train researchers to conduct research in statistical education.

In the ICMI Study *What is research in Mathematics Education and what are its results*? (Sierpisnka & Kilpatrick, 1998) it was recognised that scientific research should be guided by principles, theories and conceptual frameworks. Furthermore, obtaining a relevant research result (Nissen & Blomhoj, 1993) requires systematic and disciplined methodology to ensure the research validity and reliability. We can translate these ideas to statistics education and then two basic components of a Master's or doctorate program in statistics education are the theoretical and methodological courses.

Below we reflect on our experience in organizing a doctorate program in Mathematics Education at the University of Granada, and starting there a research group in statistics education, where 9 doctoral dissertation have been carried out in the period 1988-2001 and others are in progress. We also take into account the analysis of 91 programs in Mathematics Education from different countries (Batanero, Godino, et al., 1994) and our experience in teaching doctoral or Master's courses in several Spanish and South American universities.

THE DOCTORAL PROGRAMME AT THE UNIVERSITY OF GRANADA

The Doctoral Programme in Mathematics Education at the University of Granada was started in 1988, with only three lecturers in charge of teaching the courses and supervising research, one of them coming from the Department of Statistics and with no experience in educational research. Fortunately we counted on the help of a very experienced French research team in mathematics education: professors Michéle Artigue, Ives Chevallard, Regine Douady, André Rouchier, coordinated by Guy Brousseau, who travelled to Granada to teach some of the courses and helped in the orientation of the theses during the first four years of the programme. Starting the doctoral programme would have been quite impossible without their help and no doubt the influence of the French school in our research work is still visible.

There have been different regulations for doctoral programmes in Spain throughout this period. From 1988 to 2000, students were asked to complete 320 hours of regular course work and seminars, over two years part-time, with the possibility of spending up to 90 hours in the second year to produce a preliminary written research monograph (similar to a Masters' thesis). In the new regulations, the amount of course work is reduced to 200 hours in the first year and the second year is dedicated to produce a compulsory research monograph for a total of 120 hours. When the student finishes these two years and his/her research work is approved, he must carry out a Ph. D. dissertation (original research, supervised by a doctor expert in Mathematics Education or a related field), which usually takes 2-4 more years to complete.

Students' background

This Programme is offered within a Mathematics Education Department and most of the students who throughout these years have carried out a thesis (24 at the moment) as well as other students who are currently at different stages in their research are mathematicians. A few students came from Education or Physics. In the last few years, we received South American students with different background, although the majority still are related to mathematics. All the 9 students who finished their doctoral thesis in statistics education took a speciality of statistics during the University studies or have been teaching statistics for a number of years before entering the programme. These students then had a solid basis in mathematics and theoretical statistics; the majority of them were also acquainted with applied statistics, data analysis and statistical software. As compared to their colleagues doing dissertations in other branches of mathematics education, they had a better methodological background and were better prepared to analyse their data and carry out an empirical research.

THEORETICAL CONTENTS IN THE PROGRAMME

Although some students have experience in educational research and in teaching mathematics or statistics, the majority of them needed to complement their theoretical knowledge about education and mathematics education. Two courses (60 hours) on Theory of Mathematics Education include four main components. Although the discussion here is general, in the case of students intending to produce a thesis in statistics education, the contents are contextualised to this particular field.

Mathematics (Statistics) Education as a Scientific Discipline

We present a perspective of mathematics (statistics) education as a complex and heterogeneous social system with three interrelated components:

1. Reflective practice about teaching and learning (teachers and lecturers).
2. Scientific research, which attempts to understand teaching in general, specific didactic systems or its components (the teacher, the student, and the mathematical and statistical knowledge).
3. Didactic technology, producing teaching materials to improve instruction.

The world of practice (teachers) is focused on a group of students. Scientific researchers are engaged in building theoretical concepts. Didactic technology (or applied research) involved the production of tools for action; this is the field for curriculum designers, text book writers, etc. None of these three components operates independently from each other, nor is there a hierarchical distinction between them, and moreover their frontiers are fuzzy. It is necessary to make future researchers conscious of these distinctions, since most of them are University or secondary school teachers with strong conceptions about practical problems.

Epistemological Foundations

The complexity of educational problems confronts mathematics and statistics education with the dilemma of developing its own fundamental research to develop theories on which a coherent and productive research agenda could be based. An essential question is whether we should build an explicit conceptualisation about the nature of mathematical or statistical objects (concepts, procedures, theories, etc.), and its development at an individual and institutional level. As a part of our research work over the past 12 years and our theoretical reflections we started a

systematic inquiry into the nature, origin, meaning and understanding of mathematical objects (Godino & Batanero, 1994, 1998). This conceptualisation is also applicable to statistical objects and is based in the following assumptions:

- Mathematics is a human activity involving the solution of socially shared problematic situations, internal or external to Mathematics.
- Mathematics is a symbolic language in which problems and solutions are expressed. The systems of symbols, as culturally embodied, have a communicative function and an instrumental role, which changes the very person who uses the symbols as mediators.
- Mathematics is a logically organised and socially shared conceptual system.

From this theory, we proposes a research agenda for Mathematics and Statistics education (Batanero & Godino, 2001) and applied these ideas in many of the statistics education theses that have been carried out in Granada.

Teaching and Learning Theories

Mathematics (Statistics) Education is a scientific discipline supported by Epistemology, Mathematics, Psychology, Sociology, etc. This makes it difficult to select the teaching and learning theories to include in a program for the preparation of researchers. Because of their specificity for mathematics education and our relation with this research group we particularly take into account the theoretical results of the 'French school' of Didactic of Mathematics. We also take into account recent tendencies in the philosophy of mathematics and in Mathematics Education, as well as constructivist theories of learning.

Curricular Theories

We conceive the curriculum as an operative plan that specifies what students need to know, what teachers should do to make their students develop their knowledge, and what contexts would be appropriate for teaching and learning. We assume the following pedagogical assumptions:

- The main goal of the teacher's action in the classroom is to help students develop mathematical (statistical) reasoning, problem solving capacity, communication ability and establishing relationships between mathematics (statistics) and other disciplines.
- Special attention should be paid to the organization of teaching. Careful selection of tasks should provide students opportunities to explore relevant problems, formulate conjectures, use various representations, and communicate with classmates.
- Students should recognize the level of development of mathematics (statistics) and its applicability to other disciplines and human activities. The aim is the progressive appropriation of knowledge, which is, students' construction of a network of concepts and procedures, as well as the mastery of language.

Although the discussion is general, each student can choose a particular area (algebra, statistics, probability to analyse). For the particular case of doctoral students trying to produce a thesis in statistics education these ideas can be discussed using our books (Batanero, Godino, & Navarro-Pelayo, 1994; Batanero, 2001; Godino, Batanero, & Cañizares, 1987), which contain specific proposals for teaching Probability, Combinatorics, and Statistics according to the assumptions described.

STATISTICS EDUCATION CONTENT IN THE PROGRAMME

The amount of specific courses in statistics education have increased from only a 30 hours course in statistics education in the period 1988-1994 to 3 different courses (didactics of probability; didactics of data analysis; didactics of inference) with a total of 100 hours in the period 2000-2002. These courses are intended to complement the general course of mathematics education in providing a basic knowledge of statistics education as a specific research field, present example of different types of research in this area and help student to identify possible research problems to produce a dissertation in statistics education. Basic contents for these courses are:

- *Current situation of Statistics Education*: the IASE and ISI works, other associations, conferences, journals, discussion lists and other sources of specific bibliographic information.
- *Epistemology of Stochastics:* basic stochastical ideas, its historical genesis, different conceptions and philosophical problems around them. Different approaches to statistical inference; controversies around the use of inference and the problem of validation for empirical knowledge; data analysis: main current approaches; statistical modelling, experimenting, association and the search for causes.
- *Cognitive development:* constructivism, social interaction and the role of language. Piaget's stages in cognitive development: the case of randomness, probability and other stochastic ideas. Fischbein's ideas about intuitions and the role of instruction. Recent research on social interaction in the classroom and its influence on children's development of stochastic ideas.
- *The stochastic curriculum:* reasons, aims and content of teaching stochastics at different educational levels; didactic resources, technology, computers and the Internet. Assessment; different assessment instruments. Methodologies for teaching statistics and probability. Analysis of curricular materials and didactical units.
- *Research into students understanding and learning:* main theoretical frameworks in statistics education research. Research on students' conceptions before instruction and on conceptual change induced by specific teaching experiences; research on students' strategies and errors in problem solving or in data analysis.
- *Other research:* attitudes, social factors, comparative studies, case studies, textbooks, etc.

RESEARCH METHODOLOGY

During his /her research the student should produce measurement, survey, or observation instruments, design educational interventions, collect and analyse data. Below we describe the main methodological contents in the courses, which have ranged between 120 hours in the 1988-1990 programme to 60 hours in the 2000-2002 programme.

*Research paradigms: w*e discuss the notion of paradigm, and make a critical analysis of the most relevant paradigms in educational research that can be situated between two extreme positions. The positivist or process-product paradigm, which especially attempts to find laws and test hypotheses about behaviours and procedures related to the students' academic achievement. It is usually based on quantitative methods, systematic measurements, experimental designs, and mathematical models. The interpretative or qualitative paradigm focused on searching for the personal meaning of events, in studying the interaction between people and environment, as well as the participants thoughts, attitudes and perceptions. It is associated with naturalistic observations, case studies, narrative reports. In addition, the socio-critical paradigm tries to connect research with practice.

The Research Process: When the student identifies a research area he/she needs to systematically explore the bibliography and to focus progressively on one particular problem. From the beginning he/ she has to decide on the particular approach or paradigm and define the objectives and hypotheses, which will serve to select the variables and information needed. The complexity of the problem might lead to reduce the number of independent and dependent variables, and to control concomitant variables to guarantee the validity of conclusions. Experimental and quasi-experimental techniques to assign subjects to different conditions, or to develop questionnaires would be needed and sampling techniques should be applied to guarantee representativeness and to increase generalisability. Time and effort dedicated to these themes are very productive for doctoral students.

Data Collection: Subjects' mathematical knowledge is a complex system, not directly observable, but should be inferred from their responses to assessment tasks. These empirical indicators of the subject' s knowledge are qualitative and multidimensional. Consequently, we need varied assessment tasks: questionnaires, problems, projects, individual interviews or classroom observation. This diversity of data forces the researchers to choose different observation, survey and measurement methods and techniques.

Data Analysis: The study of the relations between the different variables in a research requires a variety of data analysis techniques. Most researchers would require the collaboration of expert statisticians to analyse their data. However, we try to provide every researcher with a basic preparation that will allow him/her a certain degree of autonomy in the initial data analysis of his/her own research; e.g., computing simple statistics or carrying out basic tests, to communicate with and consult an expert statistician when they require more complex analyses and to understand technical reports from the statistician. An important aim for future researchers is being aware of the possibilities of new data analysis techniques. Although a narrative or interpretative data analysis would be highly relevant in qualitative studies, this analysis could be complemented by exploring the structure of interactions between variables, using correspondence analysis, implicative analysis, cluster analysis, log-linear models, etc., which are applicable to qualitative variables.

STARTING A RESEARCH GROUP IN STATISTICS EDUCATION

Starting in 1988 a doctoral programme with only three possible supervisors forced us to concentrate the research topics on three basic research lines: Numerical Thinking, Theory of Mathematics Education and Statistics Education. Two of the lecturers in charge of the programme had carried out their dissertations in pure statistics and had extensive experience of statistics consultancy work in different experimental research area, the field of statistics was familiar to them in its different facets: teaching, applied and theoretical research. That experience had also served to take consciousness of the problems in understanding and applying statistics and of the interest to carry out didactical research in this area.

The fact that, after finishing their dissertations, our colleagues stayed in our department or other cities close to Granada (Jaen, Melilla) served to increase the "critical mass" of lecturers specialised in statistics education who could collaborate in supervising new students. From a few starting problems: association, combinatorics, the test of hipotheses, we gradually moved to other areas, such as probability or the normal distribution. Nine doctoral dissertation have been finished in statistics education in this period and three more are currently in progress.

The doctoral programme at the University of Granada received a great support from Spanish and other European academic authorities and this served to fund the visit from main mathematics and statistics educators who gave us courses and discussed with us our research in progress. Statistics education research received particular support through different funded projects from the Spanish Ministry of Education. Another happy circumstance that served to consolidate and impulse our work was the IASE decisions to hold the ICOTS-4 conference in Marrakesh and the 1996 IASE Round Table Conference in Granada that helped to establish new valuable contacts and collaborations that still continue. The list of theses, projects and publications carried out in the group is available from our web page http://www.ugr.es/local/batanero, which is also linked to the IASE and other statistics education web servers.

FINAL REFLECTIONS

Having finished the training of all the members in our own department (where there are now 18 lecturers with a Ph.D in mathematics or mathematics education, and also the training of other colleagues in Andalusian universities (3 in Jaen, 2 in Cordoba, 2 in Malaga) we focus now on the education of young students and South American colleagues, who, in the last years were increasingly successful in getting a grant either from their own countries or from the AECI (Spanish Agency for International Co-operation), OEI (Organisation of Iberoamerican States) or other institutions. A number of doctoral dissertations by colleagues from Argentina, Colombia, Chile, Mexico and Venezuela are being carried out in Granada. When returning to their countries they usually take over responsibility for Master's or doctoral programmes in education or in mathematics education. It is then very likely that this collaboration can serve to spread mathematics and statistics education research in South and Central America.

In this brief report we have reflected on our particular experience in the training of researchers in statistics education from a mathematics education doctoral programme, which was started with a lot of effort, but gradually developed to be the main research programme in

mathematics education in Spain and includes the larger statistics education research group in Spain. International collaboration was very important at different stages to start up the doctoral programme, and orientate the first theses. We hope this experience can encourage other researchers to start new programmes even with modest initial resources and in this way can serve to extend the interest towards statistics education research.

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