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Statistical literacy at university level: the current trends

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Abstract

Active and critical citizens, in contemporary information-driven societies, are considered to possess capacities and skills of statistical literacy. There are numerous definitions and descriptions concerning statistical literacy, statistical reasoning and statistical thinking. Thus, all these terms converge to the principle that statistical citizenship develops from school settings and relates mainly to the processes of evaluating, interpreting and communicating data. If these are not acquired on time, then students build up errors and misunderstandings. In the current paper general issues concerning Statistics Education at the University level are addressed and aspects for future research are stressed in terms of technology use, content and pedagogic approaches.

Keywords: statistical literacy; Statistics Education

1. Introduction

During the last years there has been a great interest in the field of Statistics Education. According to recent studies (i.e. Chance, 2002; Gal. 2002; Garfield & Gal, 1999; Schield, 2004; Wild & Pfannkuch, 1999; delMas, 2002), there has been intensive research regarding statistical thinking, statistical literacy and statistical reasoning. The three notions, statistical literacy, statistical reasoning and statistical thinking, are inherently fuzzy and unambiguous in defining and discriminating from one another. However, they feature the three main learning goals of teaching Statistics within the formal context (Broers, 2006).

In fact, as Chance (2002) underlines 'thinking,' 'reasoning,' and 'literacy' are used interchangeably in an effort to distinguish the understanding of statistical concepts from the numerical manipulation and graphing of data that characterize statistical practices and instruction. Is there is any correct and general definition for statistical literacy? One of the first definitions given by Wallman (1993), states that "*statistical literacy is the ability to understand and critically evaluate statistical results that permeate our daily lives–coupled with the ability to appreciate the contributions that statistical thinking can make in public and private, professional and personal decisions*" (p.1).

According to Gal (2002), statistical literacy is based on the interaction of the components which comprise knowledge elements and dispositional elements. *Knowledge elements* involve *cognitive* components such as literacy skills, statistical knowledge, mathematical knowledge, context knowledge and critical questions. On the other hand,

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dispositional elements are considered as 'non-cognitive' aspects and involve personal beliefs, dispositions and attitudes as well as the critical stance of individuals. Under these considerations the formal schooling background is not the only determinant in developing statistical skills, but statistical knowledge in an informal way should also be taken into account in learning-teaching processes.

The aim of this study is to feature Statistics Education in the development of statistical literacy, especially in the formal context at the University level. Issues concerning the content, the pedagogical approaches, the classroom practices and the importance of technological tools emerge for further discussion at a theoretical and practical level.

2. Statistical literacy in formal context

The school plays a crucial role in enhancing statistical literate students who in turn understand why and how statistics are useful in perceiving and interpreting the world and its complexity (Frankenstein, 1998). Schield (2000) states that for students to be statistically literate they have to be able to ask whether a claim *could be true* rather than if it *is true*. He goes on to differentiate between statistics by meaning mathematical models and processes and statistical literacy by meaning statistical thinking and reasoning.

Most countries include the study of basic statistical concepts and procedures in their curricula by recognizing the importance of school in the development of statistical thinking and competence in citizen formation (Batanero et al., 1994). For instance, Holmes (2000) mentions how Data Handling is incorporated in the mathematical National Curriculum for England (DEE & QCA, 2000), in Western Australia Chance and Data are included from Preschool to Year 10 (K-10 Scope & Sequence, 2007), in New South Wales in the Mathematics K-6 Syllabus (2006) chance is found among the sets of substrands, Ottaviani and Rigatti (2005) present how in Italy Data and Predictions are promoted and Peck et al (2007) describe how statistics and data analysis can be viewed as a coherent curriculum strand through problem solving activities, teachers' preparation, concept development activities.

Watson and Callingham (2003) have proposed a statistical literacy construct with six hierarchical levels that represent increasingly sophisticated thinking starting from idiosyncratic (Level 1) up to critical mathematical (Level 6). This model describes how development in statistical literacy is related to the development of statistical concepts in students. According to this model, when students leave school they are expected to possess an appreciation of every level in progression in order to be able to develop statistical knowledge and skills, communicate ideas and be critical.

Learning styles, age, personality, mood, diverse environments, teaching tools and instruction, cognitive and social skills among other factors determine the learning and construction of statistical knowledge. Along with personal development, learning can be seen as "*the process whereby knowledge is created through the transformation of experience*" (Kolb 1984, p.41). From these implications it can be supported that preschoolers, children, students and finally adults, learn in different ways as a consequence of timing (Pange, 2010). Time is important not only in terms of age but also as a factor of receiving, processing, acquiring, recognizing, filtering, expressing, evaluating information and knowledge during the learning process.

3. Statistics at University level

Usually, students before entering the University level hold wrong perceptions and misapprehensions about statistical ideas and skills (Chadjipadelis and Gastaris, 1998; Garfield, 2003). Additionally, at University level, statistics constitute a tool for solving problems in other study fields such as education, geography, social sciences or medicine (Batanero, 2005). Within these courses many students acquire abilities to manipulate definitions and algorithms with apparent competence, but cannot handle interpretative activities or data analysis of real problems (Pimenta, 2006).

According to Garfield and Ben-Zvi (2004), there are eight main 'big ideas' that are usually included in statistics instruction: data, distribution, trend, variability, models, association, samples and sampling, and inference. While designing Statistics Education pedagogies and practices apart from the diversity of students' statistical preparation, background, grade and level, issues of continuity (when to teach what), pedagogy (how to approach the content and develop desired learning outcomes) and priority (prioritizing and sequencing of topics) have to be taken into account (Garfield and Ben-Zvi, 2004).

From a more broad point of view Bryce et al (2000) indicate five topics that should be included in undergraduate degrees in statistics. They suggest skills in statistical science – mathematically based (data collection, data analysis, correlation, statistical theory such as notions of variability, probability, and confidence), skills in statistical science – non-mathematically based (communication, collaboration and project management skills), computational skills (pertaining to word-processing, data handling, and statistical computing), mathematical foundations (including calculus and linear algebra) and substantive skills (related to the interpretation of statistics in an applied context).

4. Issues in teaching Statistics at University level

4.1 General issues

Usually statistics are taught in isolation without being connected with a more general framework of research methodology and experimental design that relate to real life situations. However, Statistics should be incorporated in contexts that have meaning and stimulate students in order to participate and get eager to learn. Students should face experiences with multiple forms of work, organize and implement statistics projects and be presented with experiments, simulations and graphical representations not just as methodological teaching aids, but rather as essential means of knowing and understanding statistics (Steinbring, 1990). According to Batanero et al (2006) a statistical instruction should include all different stages of solving a real problem: planning a solution, collecting and analyzing data, checking initial hypotheses and taking appropriate decisions.

Concisely, ten principles for learning statistics were firstly proposed by Garfield (1995) and since then, they have been supported and examined through various studies. According to Garfield and Ben-Zvi (2007), learning statistics should be based on constructing knowledge, on students' active involvement, on practice doing and repetition, on estimating difficulties that may occur in understanding or misunderstanding basic concepts, on encouraging students to confront their errors, on making use of technological tools through technology-based instruction and finally on providing feedback and assessment on student's performance.

4.2 The project-based method

The project-based method is found to be very useful in teaching Statistics at University level. Either when applied in peer groups or individually a project may provide students with the opportunity to get actively involved, collaborate, plan and carry out tasks that are of their interest. For instance, while students collect and record the data of a topic they gain familiarity with the context of this research topic (Binnie, 2002). Under systematic teaching and learning activities, Statistics may assist in correcting students' erroneous perceptions and misconceptions (Chadjipadelis and Gastaris, 1995). Project-based teaching is an instructive method that enhances students to interact between them and with their educator and motivates them to explore statistical notions and processes, according to Chadjipadelis and Adreadis (2006). They carried out a study by implying that students that participated in project based practices had more positive feelings concerning statistics, believed more in the value of statistics in personal and professional life, showed greater interest in Statistics and higher levels of understanding statistical concepts.

4.3 Educators' skills and attitudes

Another issue in teaching statistics relates to educators' skills, capacities and knowledge. According to Batanero et al (2004), statistics teachers should attain a great deal of information about *'didactical knowledge'*, in terms of epistemological reflection on the meaning of concepts to be taught or as Biehler (1990) suggests on meta-knowledge, on experience in adapting this knowledge to different teaching levels and students of various levels of understanding, on critical capacity to analyze textbooks and curricula, on prediction of students' learning difficulties, errors, obstacles and strategies in problem solving, on capacity to develop and analyze assessment tests and instruments and finally on experience with good examples of teaching situations, didactic tools and materials.

The need for re-training and life-long learning of in-service educators is essential and the use of technological advancements may assist towards this direction (Pange, 1999). 'News-groups', as a web-based tool may support educators' and statisticians effort to be 'up-to-date', acquire information and communicate practices and ideas. Through this use of the Internet there is an opportunity of exploring alternative viewpoints, exchanging opinions, promoting collaborative learning and sharing knowledge and concerns about issues concerning Statistics Education (Pange, 2002).

4.4 The role of technology

Computer-based teaching is another aspect of great importance on teaching Statistics at University level, thus there is still no profound research in this area. Students as well as teachers today have access to virtual learning along with extensive and varied online resources. Hilton & Christensen (2002) evaluated the impact of incorporating multimedia presentations into traditional lectures and found that it did not improve student's learning or attitudes. Similarly, Utts et al., (2003) suggested that students in a traditional compared to a mixed setting (using Internet and traditional teaching) had no variances in their performance. In addition, Pange (2006) found that the internet and appropriately selected websites may enhance teachers' confidence and competence in teaching probabilistic and statistical notions.

In accordance to Ben-Zvi (2000), technological tools especially designed for statistics learning should be developed amongst important pedagogical aspects:

"*1. students' active knowledge construction by "doing" and "seeing" statistics,*

2. multiple opportunities for students to reflect on observed phenomena,

3. students' development of metacognitive capabilities, that is, knowledge about their own thought processes, self-regulation, and control

4. the renewal of statistics instruction and curriculum on the basis of strong synergies among content, pedagogy, and technology (Moore, 1997)" (p.128).

5. Conclusions

Statistical literacy is a key ability that characterizes active and critical citizens within information-laden societies (Gal, 2002). It is often touted as an expected outcome of schooling and as a necessary component of adults' numeracy and literacy (Garfield and Ben-Zvi, 2007). Watson (2006) sees statistical literacy as the "*meeting point of the chance and data curriculum and the everyday world, where encounters involve unrehearsed contexts and spontaneous decision-making based on the ability to apply statistical tools, general contextual knowledge, and critical literacy skills*" (p.11).

In order to produce statistically literate students with minimal misconceptions, the statistics module should be 'carefully' designed at the University level not to mention earlier classes. Thus, instruction issues should be elaborated more profoundly by taking into account the synergy of content, pedagogy and technology (Moore, 1997). Introductory courses of statistics should move from the traditional views of teaching statistics as a mathematical topic (with an emphasis on computations, formulas, and procedures) to the current emphasis on statistical reasoning and the ability to interpret, evaluate, and flexibly apply statistical ideas (Ben-Zvi, 2000). Further research in this direction would illuminate aspects of classroom practices, course format, teaching-learning processes, exploitation of statistical tools and manipulative through the means of technology.

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