STATISTICS TEACHER OF THE NEW ERA: ANOTHER SPECIALIZED MATHEMATICIAN OR A TOTALLY DIFFERENT PERSON?

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The majority of mathematics teachers have received a purely formalistic education, with little, if any, specific training in probability and statistics. Their formalist mathematical background has a negative effect on their statistical reasoning and their development as teachers of statistics. In the paper, we describe EarlyStatistics, an online professional development course in statistics education targeting European elementary and middle school mathematics teachers. To help teachers go beyond procedural understanding of statistics, the course emphasizes statistical problem-solving. Through participation in projects, experiments, computer explorations with real and simulated data, group work and discussions, participating teachers learn where the "big ideas of statistics apply and how, and develop a variety of methodologies and resources for their effective instruction.

INTRODUCTION

The significant reform efforts in statistics education witnessed in recent years have caused a movement away from statistical content emphasizing the abstract and the application of formulas and procedures, toward curricular frameworks emphasizing real-world applications of statistics and statistical problem solving (National Council of Teachers or Mathematics, 2000; Franklin et al., 2007). Changing teachers' long-held beliefs and attitudes towards statistics, however, is proving to be quite difficult. Deep-rooted beliefs about the nature of mathematics as a subject of deterministic and hierarchically-structured knowledge (Makar & Confrey, 2003) are imported into statistics, affecting instructional approaches and curricula and hampering the reform efforts. Intuition and mindset about data are systematically ignored in mathematics classroom.

Although statistics has already been established as a vital part of the school mathematics curriculum in many countries, instruction of statistical concepts is still highly influenced by the formalist mathematical tradition. There is over-emphasis on center criteria and a tendency to underestimate the effect of variability in real world settings, which is related to the emphasis of the traditional mathematics curriculum on determinism and its orientation towards exact numbers (Meletiou-Mavrotheris, 2007). Notions such as randomness and variation, which have a nature very much dependent on context, are typically presented in the classroom as rigidly established bodies of mathematical knowledge without any reference to context. Instruction fails to build bridges between students' intuitions and statistical reasoning and to convey them the relationship between the knowledge they acquire in the statistics classroom and its uses in the real world.

Statistics has been introduced into mainstream mathematics curricula without adequate attention paid to teachers' professional development. There is substantial evidence of poor understanding and insufficient preparation to teach statistical concepts among both pre-service and practicing teachers (Begg & Pfannkuch, 2004). Teachers have, for the most part, been trained in traditional mathematics classrooms, with little, if any, specific training in probability and statistics. Many of the senior teachers have never formally studied the subject. Younger teachers may have taken an introductory statistics course, such a course however does not typically adequately prepare future teachers to teach statistics in ways that develop students' intuition about data and uncertainty (Rossman, Medina & Chance, 2006). College-level statistics courses are often lecture-based, not allowing future teachers to experience the model of data-driven, activity-based, and discovery-oriented statistics they will eventually be expected to adopt in their teaching practices. As a result, the majority of teachers tend to have weak knowledge of statistical concepts and relatively deterministic epistemological sets, often sharing the same misconceptions regarding the stochastic as their students. They tend to focus their instruction on the procedural aspects of probability and statistics, and not on conceptual understanding (Nicholson & Darnton, 2003; Watson, 2001).

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The direct relationship between improving the quality of teaching and improving students' learning is a common thread emerging from educational research (Stigler & Hiebert, 1999). For it is what a teacher knows and can do that influences how she or he organizes and conducts lessons, and it is the nature of these lessons that ultimately determines what students learn and how they learn it. Thus, to achieve fundamental changes to the instructional methods and tools employed in the mathematics classroom to teach statistical and probabilistic concepts, it is critical for mathematics teachers to have rich teaching and learning experiences in statistics and its pedagogy.

The article provides an overview of *EarlyStatistics*, a 3-year EU-funded project (2005-2008), which was proposed in response to the need for improving the quality of statistics instruction offered in European schools. Recognizing teachers' ongoing professional development and learning as a linchpin of instructional innovation and success for their students (Ginsberg, 2003), the project exploited the affordances offered by open and distance learning technologies to offer high quality experiences in statistics education to teachers dispersed across Europe. A consortium of five higher education institutions from four countries (Cyprus, Greece, Spain, Norway), developed and pilot tested an intercultural online professional development course in statistics education targeting European elementary and middle school mathematics teachers. The course aims at helping teachers improve their pedagogical and content knowledge of statistics through exposure to innovative web-based educational tools and resources, and cross-cultural exchange of experiences and ideas.

EARLYSTATISTICS PEDAGOGICAL AND DIDACTICAL APPROACH

EarlyStatistics has adopted "learning" and "community" rather than "instructional" models of professional development (Barab, Kling & Gray, 2004). A central conviction underlying the course design is that learning is a social act best supported through collaborative activities, and thus learning as part of an online community of practice can provide a useful model for teacher professional development. The *EarlyStatistics* course promotes intercultural awareness and exchange of experiences and ideas among European teachers, offering an environment in which participants collectively generate knowledge for their professional lives (Gordon, Petocz & Reid, 2007). Teachers interact and learn about statistics by engaging in joint activities and discussions, helping each other, and sharing best pedagogical strategies. Through these interactions, they build relationships and construct a community that supports best practices and innovation in statistics instruction.

EarlyStatistics participants are provided with ample opportunities for interactive and collaborative learning. They are actively involved in constructing their own knowledge, through their participation in authentic educational activities such as projects, experiments, computer explorations with real and simulated data, group work and discussions. Central to the course design is the functional integration of technology with existing core curricular ideas, and specifically, the integration of new types of statistics education tools (the dynamic statistics software Tinkerplots© and Fathom©), as well as a variety of activities and resources available online (e.g., simulations, animations, video clips, etc.), that stimulate and engage teachers and provide them with the opportunity to model and investigate real world problems of statistics

EARLYSTATISTICS COURSE CONTENT AND STRUCTURE

The *EarlyStatistics* course design focuses on activity-based learning. The course aims at enriching teachers' (i) knowledge of and about statistics; (ii) knowledge about teaching and learning, and (iii) practical knowledge (Azcárate et al., 2008), through hands-on and computer-based practice, experimentation, intensive use of simulations and visualizations, feedback from each other, and reflection. Teachers participate in a number of collaborative and participatory activities that help them improve their content and pedagogical knowledge of statistics and, being actual practitioners, then apply what they learn to a real classroom setting.

The course lasts for 13 weeks, and is made up of six Modules. In Modules 1-3 (Weeks 1-7), the focus is on enriching participants' statistical content and pedagogical knowledge by exposing them to similar kinds of learning situations, technologies, and curricula as those they should employ in their own classrooms. To help teachers go beyond procedural understanding and acquire a well-organized body of knowledge, the course emphasizes and revisits a set of central

statistical ideas rather than presenting statistical content as a sequenced list of curricular topics. The conceptual "Framework for Teaching Statistics within the K-12 Mathematics Curriculum" (Franklin et al., 2007), has been used to structure the content presentation. This framework uses a spiral approach so that instructional programs from pre-kindergarten through high school encourage students to gradually develop understanding of statistics as an investigative process with four components: (i) clarifying the problem at hand and formulating questions that can be answered with data; (ii) designing and employing a plan to collect appropriate data; (iii) selecting appropriate graphical or numerical methods to analyze the data, and (iv) interpreting the results (Franklin et al., 2007). The spiral organization of content aims at helping teachers understand statistics as a comprehensive approach to data analysis. Using real data, active learning and technology, participating teachers learn where the "big ideas" of statistics apply and how, and develop a variety of methodologies and resources for their effective instruction at different levels of schooling.

The "Conducting a Statistical Study Project", presented in Table 1, is a characteristic example of the activities in which teachers engage during Modules 1-3.

Table 1. Conducting a Statistical Study Project

MODULE 1: ACTIVITY 3

This is Phase 1 of the "Conducting a Statistical Study" project, which will span the first seven weeks of the course. In the project, you will work in small groups of 4-5 teachers of similar grade levels to carry out a real statistical study to investigate one or more questions of your choice. Completing the project will help you see the "big picture" of statistics by taking you through all four stages of the statistical problem solving process: posing the question, collecting the data, analyzing the data (using appropriate technological tools), and interpreting the results. This will deepen your content knowledge of statistics and will serve as a model as to the type of learning situations, technologies and curricula you should employ in your own statistics classroom.

Phase 1 (Weeks 1-2): Pose a question

Working jointly with your group, do the following:

1) Decide on a topic that you think would be of interest to students of your grade level.
2) Formulate one or more questions that would be appropriate for your grade level, and that could be addressed by collecting and analyzing data.

MODULE2: ACTIVITY 3

This is Phase 2 of the "Conducting a Statistical Study" project. In this phase, you will collect data to address the question(s) you posed in Phase 1.

Phase 2 (Weeks 3-4): Collect Data

In this task, you will work with your group to devise and carry out a plan for collecting data to answer the question(s) you posed in Phase 1:

Working jointly with your group, do the following:

1) Choose a method of data collection that will be appropriate to use for gathering information to address the question(s) posed in Phase 1.
2) Devise a plan for collecting the data: What will you measure? How will you measure it? How many subjects will you include in your study? How will you choose subjects? Are there any practical considerations and/or limitations?
3) Make predictions as to what you expect to see in the data.
4) Do the data collection based on the plan. Keep notes of any problems/issues that might arise.

MODULE3: ACTIVITY 3

This is Phase 3 of the "Conducting a Statistical Study" project. In this phase, you will analyse and interpret the data you collected in the previous phases of the project.

Phase 3 (Weeks 5-7): Analyze and Interpret

In Phase 3, you will analyze the data collected during Phase 2, and interpret the results of this analysis:

1) Analyze the data collected during Phase 2 using a dynamic statistics software (Tinkerplots© or Fathom©).
1) Interpret the results of the data analysis in relation to your original question(s).
2) Prepare a report presenting the study and its findings. The report should be made up of four sections:
   Section 1. Purpose of the Study: Describe the study purpose, and the question(s) it was set to answer.
   Section 2. Method: Discuss the data collection method employed and the data analysis techniques applied
   Section 3. Results: Present the evidence from your analysis (graphical and numerical) to address each of the issues given in the problem scenario.
   Section 4. Discussion: Reflect on what you learned from the study. Discuss potential drawbacks of the methodology employed and of ways you would tackle these limitations if you were to repeat this study.

When you finish writing the report, upload it (.doc, .pdf) in your e-portfolio.

In Modules 4-6, the focus shifts to classroom implementation issues. Teachers customize and expand upon provided materials (Module 4; Weeks 8-9), and apply them in their own classrooms with the support of the design team (Module 5; Weeks 10-11). They write up their experiences, including a critical analysis of their work and that resulting from their pupils. Once the teaching experiment is completed, they report on their experiences to the other teachers in their group, and also provide video-taped teaching episodes and samples of their students' work for group reflection and evaluation (Module 5; Weeks 12-13). Teachers exchange ideas and insights as to how to further improve their teaching practice and to increase their students' achievement.

EARLYSTATISTICS MODE OF DELIVERY

EarlyStatistics has a hybrid format. At the beginning, teachers gather together to attend a one-week intensive seminar. They are introduced to the objectives and pedagogical framework underlying the course, and get familiarized with the facilities offered by the e-Learning environment. More importantly, they get the opportunity to meet and interact with each other, thus mitigating the problem of trust and social presence online. The remainder of the course is delivered online, by utilizing the project information base for teaching, support and coordination purposes. In addition to the course content, the site offers access to various other links and resources: (i) *Technologically enhanced curricular and instructional materials* for the teaching and learning of statistics in the elementary and middle school; (ii) *A digital Video Case Library* containing segments of real teaching episodes, obtained in the classrooms of the teachers participating in the pilot delivery of the course, representing the landscape of practice in statistics instruction throughout Europe; (iii) *A database with Student Work Samples* developed through contributions of the participating teachers, providing examples of good practice in European schools; (iv) *Collaboration tools* for professional dialogue and support including email, conferencing, chat rooms, discussion forums, wikis, etc.; (v) *Reports and articles* developed through the project; (vi) *Links to statistics education resources* available on the Internet.

In order to offer teachers flexibility and to accommodate different time zones, the largest portion of the course is delivered asynchronously. Asynchronous means of communication include discussion forums and mail groups. There is also some synchronous communication through use of technologies such as audio/video streaming, and videoconferencing. One-way informational postings such as articles and videos also serve as objects for supporting interaction.

Teachers work according to a loose schedule. Each module involves a range of activities, readings and contributions to discussion, and completion of group and/or individual assignments. Online moderated discussions allow the course participants to share ideas, and instructional strategies. Teachers are provided a space to discuss and grapple with the complexities of teaching statistics, foster alternative perspectives and apply educational theory to practice (Kayler & Weller, 2007).

EVALUATION OF *EARLYSTATISTICS*

In *EarlyStatistics*, evaluation was an integral part of the project design. It was a process carried out at every stage of the project, in order to ensure that all key activities were performed on time and effectively by the consortium partners, and that necessary revisions or improvements to the project's methodologies, products, and outcomes are timely identified. It included both formative and summative assessment tools and protocols and services, and was conducted both internally and externally. The main external evaluation occurred during the pilot delivery of the *EarlyStatistics* course and the follow-up classroom experimentation. The pilot delivery took place during the final year of the project in three of the partner countries (Cyprus, Greece, Spain). Fourteen teachers participated in the pilot delivery. To evaluate the applicability and success of the course, there was also a follow-up classroom experimentation. Participating teachers developed and delivered teaching episodes integrating the use of the course tools and resources provided to them. Multiple forms of assessment were used to collect and document evidence of changes in teachers' pedagogical and content knowledge of statistics, their attitudes towards the subject, and in their teaching practices, as a result of participating in the professional development course: pre- and post- questionnaires, video-taping of classroom episodes, teacher and student interviews, samples of student work, and use of statistics automatically generated by the online information base. The

analysis of the obtained data informed the revision of the course pedagogical frameworks, instructional and curricular materials, as well as the tools and resources of the course information base.

In brief, the feedback from the target user groups from all partner countries, as well as from external experts regarding the course content, services, and didactical approaches was generally very positive. Key conclusions from the analysis of the user feedback were that *EarlyStatistics* met its objectives because it helped improve teachers' pedagogical and content knowledge of statistics by offering interactive, technology-rich instructional materials and services that enhance the teaching and learning process, and by providing course participants the opportunity to collaborate with other teachers and begin the construction of a community of practice. Moreover, data obtained from the teaching interventions in the course participants' classrooms suggest positive gains in student learning and attitudes towards statistics. Of course, despite the overall success of the pilot course a number of shortcomings were also identified. The biggest difficulty experienced by the consortium was in the successful building of an online community of teaching practitioners. The course participants' overburdened schedules and the diversity in their cultural and professional backgrounds made the establishment of a functional online community of practice quite challenging. The *EarlyStatistics* team experienced similar disappointment to Gould and Peck (2005), with much lower than anticipated level of learner-to learner interaction (for more details see Meletiou-Mavrotheris et al., 2008).

After final revisions of the *EarlyStatistics* course based on feedback from the pilot delivery and the follow-up classroom experimentation, and updating of the information base with the latest version of all content, the course entered the EU Lifelong Learning-Comenius database for European wide recruitment. It will be offered to the European educational community as a Comenius in-service course targeting mathematics teachers. The *EarlyStatistics* course has been scheduled for offering three times during 2009, in two of the partner countries (Cyprus and Greece). The consortium intends to continue offering the course in subsequent years, thus increasing access to large numbers of teachers involved in statistics education.

CONCLUSIONS

If the statistics classroom is to be an authentic model of the statistical culture, it should provide ample opportunities for exploration and experimentation with stochastical ideas in varied contexts. It should encourage statistical inquiry and data modeling rather than teaching methods and procedures in isolation (Lehrer & Schauble, 2004). The arid, context-free landscape on which so many examples used in statistics teaching are built ensures that large numbers of students never see, let alone engage in, statistical reasoning. Thus, to help students develop a data-oriented mindset and robust data literacy skills, there ought to be significant changes to the instructional methods and tools typically employed in the classroom to teach statistical concepts. Acknowledging the central role of teachers in educational reform, the EU-funded project *EarlyStatistics* aimed to enrich European children's learning of statistics by offering their teachers a high-quality professional development course that seamlessly combines best pedagogical practices with contemporary technologies, including the Internet for maximum flexibility.

The *EarlyStatistics* consortium has incorporated into the course design best pedagogical practices in statistics education, adult education, and distance learning. The course is based on current pedagogical methodologies utilizing collaboration, statistical investigation, and problem-solving. Particular care has been taken to build on participating teachers' knowledge and experiences, and to promote collaborative and participatory learning. Teachers from different countries improve their content and pedagogical knowledge of statistics through open-ended investigations, simulations, visualizations, collaboration and reflection on one's own and on others' ideas and experience. During the follow-up teaching experimentation, they get the opportunity to apply what they learn in the course to a real classroom setting. Use of these strategies motivates teachers, and helps them to make the difficult leap from professional development activities to classroom practice.

REFERENCES

Azcárate, P., Serradó, A., Cardeñoso, J. M., Meletiou-Mavrotheris, M., Paparistodemou, E., & Mavrotheris, E. (2008). An On-Line Professional Environment to Improve the Teaching of Statistics. 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 and 2008 IASE Round Table Conference*, Monterrey, Mexico.

Barab, S., Kling, R., & Gray, J. (2004). Introduction: Designing for virtual communities in the service of learning. In K. R. Barab, and J. Gray (Eds.), *Designing for virtual communities in the service of learning*. Cambridge: Cambridge University Press.

Begg, A., & Pfannkuch, M. (2004). *The School Statistics Curriculum: Statistics and Probability Education Literature Review*. University of Auckland, Auckland Uniservices Limited.

Franklin, C. A., Kader, G., Mewborn, D., Moreno, J., Peck, R., Perry, M., & Scheaffer, R. (2007). *Guidelines for assessment and instruction in statistics education* (GAISE) *report: A pre-K–12 curriculum framework*. Alexandria, VA: American Statistical Association.

Ginsberg, M. B. (2003). *Motivation matters: A workbook for school change*. San Francisco: Jossey-Bass.

Gould, R., & Peck, R. (2005). Inspiring Secondary Statistics. *MSOR Connections, 5*(3). Online: http://mathstore.gla.ac.uk/headocs/53inspiringstats.pdf.

Gordon, S., Petocz, P., & Reid, A. (2007). Tools, artefacts, resources and pedagogy—stories of international statistics educators. In P. L Jeffery (Ed), *Australian Association for Research in Education 2006 Conference Papers*, AARE, Adelaide. Retrieved March 25, 2008 from: http://www.aare.edu.au/06pap/gor06358.pdf.

Kayler, M., & Weller, K. (2007). Pedagogy, Self-Assessment, and Online Discussion Groups. *Educational Technology & Society, 10*(1), 136-147.

Lehrer, R., & Schauble, L. (2004). *Contrasting Emerging Conceptions of Distribution in Contexts of Error and Natural Variation.* Chapter prepared for the 33rd Carnegie Symposium on Cognition, "Thinking with Data," June 4-6, Pittsburg, PA.

Makar, K., & Confrey, J. (2003). Chunks, Clumps, and Spread Out: Secondary Preservice Teachers' Informal Notions of Variation and Distribution. In C. Lee (Ed.), *Reasoning about Variability: A Collection of Current Research Studies* [CDROM]. Dordrecht, the Netherlands: Kluwer Academic Publisher.

Meletiou-Mavrotheris, M. (2007). The Formalist Mathematical Tradition as an Obstacle to Stochastical Reasoning. In J. P. Van Bendegem and K. François (Eds.), *Philosophical Dimensions in Mathematics Education* (pp.131-155). Brussels: Springer.

Meletiou-Mavrotheris, M., Paparistodemou, E., Mavrotheris, E. Azcárate, P., Serradó, A., & Cardeñoso, J.M. (2008). Teachers' Professional Development in Statistics: The Earlystatistics European Project. In C. Batanero, G. Burrill, C. Reading and A. Rossman (Eds.), *Joint ICMI/IASE Study: Teaching Statistics in School Mathematics. Challenges for Teaching and Teacher Education. Proceedings of the ICMI Study and 2008 IASE Round Table Conference*, Monterrey, Mexico.

National Council of Teachers of Mathematics. (2000). *Principles and Standards for School Mathematics*. Reston, VA: Author.

Nicholson, J. R., & Darnton, C. (2003). Mathematics teachers teaching statistics: What are the challenges for the classroom teacher? *In Proceedings of the 54th Session of the International Statistical Institute.* Voorburg, Netherlands: International Statistical Institute.

Rossman, A., Medina, E., & Chance, B. (2006). A post-calculus introduction to statistics for future secondary teachers. In A. Rossman & B. Chance (Eds.), *Proceedings of the Seventh International Conference on Teaching Statistics*, Salvador, Brazil. Voorburg: The Netherlands: International Statistical Institute.

Stigler, M., & Hiebert, J. (1999). *The Teaching Gap*. Free Press.

Watson, J.M. (2001). Profiling teachers' competence and confidence to teach particular mathematics topics: The case of chance and data. *Journal for Mathematics Teacher Education, 4*(4), 305-337.