Online Communities of Practice Enhancing Statistics Instruction: The European Project EarlyStatistics

Maria Meletiou-Mavrotheris and Efstathios Mavrotheris
Cyprus College, Cyprus
meletiou@cycollege.ac.cy
mavrotheris@cycollege.ac.cy

Abstract: Acknowledging the fact that teachers are at the heart of any educational reform effort, the European Union funded project EarlyStatistics aims to enrich European children's learning of statistics by offering their mathematics teachers a high-quality online professional development program. A central conviction underlying the design of the program is that learning as part of a community of practitioners can provide a useful model for teacher professional development. Teachers participating in the program will form a virtual community of practice, which will support best practices and innovation in statistics education by providing access to a wide array of colleagues, discussions, and resources eluding teachers in their workplaces.

Keywords: community of practice, professional development, statistics, distance education

1. Introduction

The Lisbon European Council of 2000 placed the development of a knowledge-based society at the top of the Union's policy agenda, considering it to be the key to the long-term competitiveness and personal aspirations of its citizens. Statistics education is a key factor in achieving the objective of an educated citizenry. In a world where the ability to analyse, interpret and communicate information from data are skills needed for daily life and effective citizenship, statistical concepts are occupying an increasingly important role in mathematics curricula. Statistics education is becoming the focus of reformers in mathematics education as a vital aspect of the education of citizens in democratic societies (National Council of Teachers of Mathematics [NCTM], 2000). Despite the larger place for statistics in mathematics curricula, the research literature indicates that people continue to have poor statistical reasoning even after having formally studied the subject. Most college-level students and adults have little understanding of data beyond the simple – and often misleading – bar charts and pie charts encountered in the media (Rubin, 2002), and exhibit a strong tendency to attribute deterministic explanations to situations involving chance (e.g. Hirsch and O' Donnell, 2001). While university level statistics instruction can indeed be successful in helping students improve their stochastical reasoning (e.g. Meletiou-Mavrotheris and Lee, 2002), poor intuitions and biases acquired early on can be extremely difficult to change (Fischbein, 1975). It is now widely recognised by leaders in mathematics education that the foundations for statistical reasoning should be built in the earliest years of schooling rather than being reserved for high school or university studies (NCTM, 2000).

Statistics has already been established as a vital part of the school mathematics curriculum in many countries. However, instruction of statistical concepts is, similarly to the college level, still highly influenced by the formalist mathematical tradition. Deep-rooted beliefs about the nature of mathematics as a subject of deterministic and hierarchically-structured knowledge are imported into statistics (Makar and Confrey, 2003), affecting instructional approaches and curricula and acting as a barrier to the kind of instruction that would provide students with the skills necessary to recognise and intelligently deal with uncertainty and variability. Intuition and mindset about data and variation are systematically ignored in the mathematics classroom (Meletiou-Mavrotheris and Stylianou, 2003). One of the most important factors in any educational change is the change in teaching practices. Teachers are in the critical path to the implementation of any innovation (Frykholm, 1999). The direct relationship between improving the quality of teaching and improving students' learning in mathematics is a common thread emerging from educational research (Stigler and Hiebert 1999). For it is what a teacher knows and can do that influences how she or he/she organises and conducts lessons, and it is the nature of these lessons that ultimately determines what students learn and how they learn it. Statistics has been introduced into mainstream math curricula without adequate attention paid to teachers' professional development. As Lajoie and Romberg (1998) point out, statistics may be as new a topic for teachers as for children. The majority of teachers have been trained in very traditional mathematics classrooms with little or no exposure to statistical concepts, and, as a result, have very limited knowledge of statistical content and its pedagogy. Many of the senior teachers have

Reference this paper as:
Meletiou-Mavrotheris M and Mavrotheris E (2007) "Online Communities of Practice Enhancing Statistics Instruction: The European Project EarlyStatistics" *The Electronic Journal of e-Learning* Volume 5 Issue 2, pp 113 - 122, available online at www.ejel.org

never formally studied statistics. Younger teachers may have taken an introductory statistics course at college, 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 et al., 2006). College-level statistics courses are often lecture-based and do not allow pre-service 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.

There is substantial evidence of poor understanding and insufficient preparation to teach statistical concepts among both pre-service and practicing teachers (Carnel, 1997; Begg and Edward, 1999). Most teachers are likely to have a weak understanding of the statistical concepts they are expected to teach and relatively deterministic epistemological sets, often sharing the same misconceptions regarding the stochastic as their students (Carnel, 1997). As a result, they tend to focus their instruction on the procedural aspects of probability and statistics, and not on conceptual understanding (Nicholson and Darnton, 2003; Watson, 2001). 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. In order to make statistical thinking accessible by all students, there ought to be fundamental changes to the instructional practices, curricular materials, tools and cognitive technologies employed in the classroom to teach statistical and probabilistic concepts. If the statistics classroom is to be an authentic model of the statistical culture, it should provide ample opportunities for experimentation with stochastical ideas in varied contexts. It should encourage statistical inquiry and data modelling rather than teaching methods and procedures in isolation (Lehrer and Schauble, 2004). It is only through exploration and experimentation that students will appreciate the wide applicability and practical usefulness of statistical tools. Advances of technology provide us with new tools and opportunities for the teaching of statistical concepts to young learners. These new technological tools are, in fact, designed explicitly to facilitate the visualisation of statistical concepts by providing a medium for the design of activities that integrate experiential and formal pieces of knowledge, allowing the user to make direct connections between physical experience and its formal representations (Pratt, 1998; Meletiou-Mavrotheris, 2003; Paparistodemou and Noss, 2004). Having such a set of tools widely available to students has the potential to significantly change the curriculum—to give students access to new mathematical topics and insights by removing computational barriers to inquiry (Rubin, 1999). Students can experiment with statistical ideas, articulate their informal theories, use them to make conjectures, and then use the experimental results to test and modify these conjectures. There is evidence that use of such software in the statistics classroom promotes conceptual change in students and leads to the development of a more coherent mental model of key statistical and probabilistic concepts (Bakker, 2003; Hammerman and Rubin, 2003).

Technology advances, and especially web-based training, also provide new opportunities for teacher professional development. Internet technologies make it possible to overcome restrictions of shrinking resources and geographical locations and to offer, in a cost-effective and non-disruptive way, high quality collaborative learning experiences to geographically dispersed teachers across Europe. The web offers the potential for teachers in different countries to collaborate and build communities of practice in social constructivist learning environments. Collaborative and participatory communities of teachers have been shown to act as vehicles that promote teacher learning and development (Tinker and Haavind' Concord Consortium 1997). In this article, we provide an overview of EarlyStatistics, a project funded by European Union under the Socrates-Comenius action, which was designed in response to the high level of interest in statistics and the need for further improving the quality of statistics education offered in European schools. EarlyStatistics aims to provide high quality online professional development in statistics education to elementary and middle school mathematics teachers around Europe. The project harnesses the power of the Internet to provide European teachers with access to a wide array of colleagues, discussions, and resources eluding them in their workplaces (Zern, 2002). It supports the development of a virtual community of practice that will help teachers to improve their teaching practices in statistics by exchanging ideas and sharing best pedagogical strategies (Gray, 2004).

2. Project description

2.1 2.1 aims and objectives

The overall aim of EarlyStatistics, which began in October 2005 and will run for three years, is to

enhance the quality of statistics education offered in European elementary and middle schools by facilitating intercultural professional development of teachers using exemplary web-based educational tools and resources. Acknowledging the fact that teachers are at the heart of any educational reform effort the project consortium, comprised of five partner institutions in four European countries (Cyprus, Greece, Norway, and Spain), utilises distance education to offer high-quality professional development experiences to geographically-dispersed teachers across Europe. More specifically, the project has the following objectives:

- Developing and pilot testing an intercultural online professional development course in statistics education for elementary and middle school teachers. The design of the course is based on current pedagogical methodologies utilising collaboration, statistical investigation, and exploration with online interactive problem-solving activities.
- Conducting a teaching intervention into the classrooms of the teachers attending the pilot professional development course. The materials and resources developed will be evaluated and revised through real-classroom implementation.
- Developing a multilingual information base to support and promote the program's activities and objectives by offering open access to the professional development course content and pedagogical approach, and to various other links and resources.
- Initialising networking among teachers across Europe by building an online community for the exchange of ideas, content, tools, and instructional practices relating to statistics education. The long-term objective is to sustain and, if possible, expand this community into a pan-European network of communication.
- Developing a pedagogical framework that provides recommendations on how to take advantage of available web-based technologies for the effective delivery of high-quality online teacher professional development in statistics education through the establishment of a virtual community of practice.

2.2 Pedagogical and didactical approach

The process of improving student learning through technology integration is never solely a technical matter, concerned only with properties of educational hardware and software (Shamatha et al., 2004). Research on cognition and learning has recently been synthesised to focus on four components that are fundamental for the successful establishment of any learning environment: learner, knowledge, community, and assessment (National Research Council [NRC], 2000). These four interlinked components are essential for the successful establishment of any learning environment, whether for student or teacher learning. Thus, they form a theoretical framework on which to base an understanding of the necessary characteristics of an effective learning environment (Shamatha et al., 2004). This Effective Learning Environment Framework was employed in the study to guide the design of the EarlyStatistics professional development program. The program learning environment is carefully designed to be learner-centred, community-centred, knowledge-centred, and assessment centred.

2.2.1 Learner-centred environment

Distance education is a useful framework for in-service teacher training, but it can represent a large variety of pedagogical perspectives. The most common approach is to follow a highly structured format, setting objectives and sub-objectives in detail and designing tasks to fit these objectives. EarlyStatistics adopts a very different approach to teacher online professional development. Recognising the fact that professional development is most effective when deeply contextualised in the teacher's professional activity (Smylie, 1995) and that teachers will bring a diverse variety of strategies into the program as a result of their own professional experiences, the project uses an approach that respects and utilises teachers' professional knowledge. The distance education environment is being designed as a framework for flexible learning (Collis and Moonen, 2001), regarding teachers as the main agents of their professional development, supported by an environment rich in challenges and interactions. Rather than using text-based, static content, that tends to be the norm in distance education of mathematics/science courses, teachers will be provided with ample opportunities for interactive learning through use of contemporary multimedia and Internet technologies. We foster a supportive and engaging learning environment, in which the teachers will be actively involved in constructing their own knowledge, through their own experiences and participation. We will engage participating teachers in the process of learning and help them develop

their pedagogical and content knowledge of statistics through authentic educational activities such as projects, experiments, and computer explorations with real and simulated data, group work, and discussions. This active, learner-centred environment, will serve as a model to the participating teachers as to kind of learning situations, technologies and curricula they should employ in their own classrooms.

2.2.2 Knowledge-centred environment

In addition to being learner-centred, EarlyStatistics also has a clear focus on learning objectives. It aims to improve teachers' content and pedagogical knowledge of statistics. To help teachers to go beyond procedural and rote memorisation and to acquire a well-organised body of knowledge (NRC, 2000), the professional development program under construction emphasises and revisits a set of central statistical ideas (GAISE, 2005), rather than presenting statistical content as a sequenced list of curricular topics. The conceptual "Framework for Teaching Statistics within the K-12 Mathematics Curriculum", developed by a group of leading statistics and mathematics educators (GAISE, 2005), is being used to structure the presentation of content. 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 that involves 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 analyse the data, and (iv) interpreting the results. This spiral organisation of content will help teachers understand statistics as a comprehensive approach to data analysis. Using real data, active learning and technology, participating teachers will learn where the "big ideas" of statistics apply and how, and will develop a variety of methodologies and resources for their effective instruction at different levels of schooling.

2.2.3 Community-centred environment

Central to the design of EarlyStatistics is the belief that learning as part of a community of practice can provide a useful model for teacher professional development (Barab and Duffy, 2000). Community of practice (Wenger, 1998) is a theoretical construct grounded in an anthropological perspective that examines how adults learn through social practices (Gray, 2004). A community of practice consists of a group of individuals with a shared domain of expertise, who engage in a process of collective learning about practices that matter to them (Wenger, 1998). Teachers participating in EarlyStatistics will interact and learn about statistics by engaging in joint activities and discussions, helping each other, and sharing best pedagogical strategies. Through these interactions, they will build relationships and form a community that will support best practices and innovation in statistics instruction. This online community of practice, which will promote the sharing of multiple, multinational perspectives, will shape not only the teachers' identity as practitioners, but also the identity of the practice itself (Gray, 2004).

2.2.4 Assessment-centred environment

Assessment is an integral component of EarlyStatistics. It is aligned with learning goals, focusing on understanding of key ideas and not just on skills, procedures, and computed answers (GAISE, 2005). The learning environment is being designed so as to enable the research team to continuously monitor teachers' progress and to provide timely feedback. We will use a multitude of assessment instruments to evaluate, while at the same time also help to improve, teachers' evolving ideas about statistical concepts and their instruction. Moreover, teachers will be provided with multiple opportunities for self-assessment. Most of the hands-on and technology-supported instructional activities developed through the program require teachers to first make conjectures about the expected results, then to test these conjectures through computer simulations or other data explorations, and finally to reflect on and to evaluate on their results and to compare and contrast them to those of other people. There will also be several low-stakes assessments included for participants to monitor their own progress, as well as some infrequent (Gould and Peck, 2004).

2.3 Project outputs

The following outputs are expected as a result of the EarlyStatistics project activities:

2.3.1 Curricular and instructional materials for statistics teaching and learning

The consortium has/will spend the first two years of the project in designing and developing, using contemporary web-based tools and resources, a line of research-based curricular and instructional materials on statistics for elementary and middle school teachers and students to be used during the professional development course. Central to the development of the material is the functional integration of technology with existing core curricular ideas, and specifically, the integration of new types of tools (e.g. the dynamic statistics software Fathom© (Finzer, 1999), and Tinkerplots© (Konold, 2005)), which will provide teachers, and subsequently their students, with the opportunity to model and investigate real world problems of statistics. The course material is being produced in the partners' national languages, as well as in English. This material, which will be evaluated and revised through real-classroom implementation, will be added to the project information base (see 2.3.4 below).

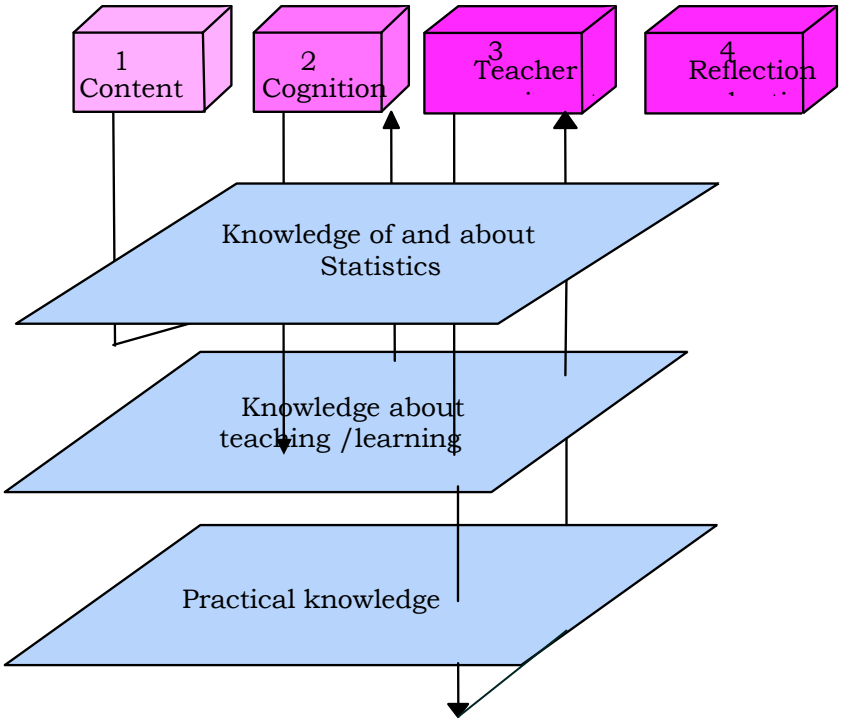

Figure 1: Structure and content of earlystatistics professional development course

2.3.2 A professional development course in statistics education for elementary and middle school teachers

The main outcome of the project will be the professional development course in statistics education for elementary and middle school teachers. The course is currently under development, and will be pilot tested during the final year of the project with a group of 30-40 teachers from the four partner countries. As seen in Figure 1, the course will aim at enriching the participating teachers' (i) knowledge of and about statistics; (ii) knowledge about teaching and learning, and (iii) practical knowledge. This will be achieved through a four-stage course that will last for 13 weeks. During the first stage (weeks 1-4), the emphasis will be on enriching the participants' content knowledge of statistics. Through hands-on and computer-based practice and experimentation, intensive use of simulations and visualisations, feedback from each other and reflection, teachers will come to gain better understanding of some of the bedrock concepts in probability and statistics that should be integrated into the elementary and middle school mathematics curriculum. Teachers will then spend the next four weeks (weeks 5-8), focusing on children's learning and what is required to involve them in learning about statistics. They will explore a broad range of topics of interest to the statistics teacher, including computer-supported teaching (use of educational software, Internet resources etc.), curriculum issues (e.g. role of statistics in the national and European mathematics curricula), and statistics education research (development of statistical reasoning in children, common student misconceptions, etc.). At a next stage (weeks 9-11), teachers will undertake a teaching experiment.

They will customise and expand upon materials provided to them, and apply them in their own classrooms with the support of the design team. Teachers will write up their experiences, including a critical analysis of their work and that resulting from their pupils. This will help them to reflect on their practice and apply self-criticism constructively. Finally, once the teaching experiment is completed, teachers will report on their experiences to the other teachers in their group, and will also provide samples of their students' work for group reflection and evaluation (weeks 12-13). They will exchange ideas and insights as to how to further improve their teaching practice and to increase their students' achievement.

Since the course will contain both theoretical and practical content, and will be used for the education of adult learners, we assume that the best approach is to present content in a way that is relevant for the teachers. Teachers will participate in a number of collaborative and participatory activities that will help them improve their content and pedagogical knowledge of statistics, and, being actual practitioners, will then apply what they learn in the course to a real classroom setting. The course will be delivered, for the most part, online through text, illustrations, animations, audio/video, technology-rich interactive problem-solving activities, and multilingual interfaces. The instructional content and services on the project dedicated information base will be utilised for teaching, support and coordination purposes. The course material will also be available in CD/DVD format to overcome potential bandwidth limitations. To offer teachers flexibility and to accommodate different time zones, the largest portion of the course will be delivered asynchronously. Asynchronous means of communication will include discussion groups and mail groups. There will also be some synchronous communication through use of technologies such as digital blackboards, audio/video streaming, and videoconferencing. One-way informational postings such as articles and videos will also serve as objects for supporting interaction (Barab et al., 2001a). Additionally, there will be a small number of face-to face meetings with local teachers.

While there will not be specific 'classroom hours,' teachers will work in teams according to a loose schedule. Each week will typically involve a range of activities, readings and contributions to discussion, as well as completion of group assignments. Some weeks will also require teachers to create something, e.g. a PowerPoint presentation, which will be posted on the information base. The course will give special consideration to sociability issues that are important in establishing a functional online community of teaching practitioners. It will employ pedagogical and technology structures that will support the community's shared purpose. The project information base will offer a variety of tools for professional dialogue and support (e.g. discussion forums, chat rooms, application sharing etc.). A number of strategies will be employed to encourage online dialogue and collaboration among community members, including the following:

- Participants will be assigned to small groups, and each group will be facilitated by an instructor
- Participating groups will receive periodic milestone group assignments
- Group, as well as whole class, discussion questions will be assigned.
- Monitored chat rooms and/or discussion forums will allow teachers to discuss and share content, ideas, and instructional strategies.

The course will be facilitated by members of the research team with expertise in statistics education. Their role will be to guide discussions, to encourage full, thoughtful involvement of all participants, and to provide feedback. Facilitators will help to deepen the learning experience for course participants by encouraging productive interaction and critical reflection on workplace practices (Gray, 2004). This will assist in developing and sustaining the online community of participating teachers over a period that will extend beyond the project lifetime.

2.3.3 A pedagogical framework for the effective delivery of high-quality online professional development in statistics education

At the initial stage of the *EarlyStatistics* project, the pedagogical and technical experts in the consortium worked jointly to develop a draft pedagogical framework to guide the design and delivery of the professional development course and, consequently, of the infrastructure and services for the dedicated information base that will support the project activities and outputs. This framework provides expert and practitioner recommendations for the effective delivery of online professional development to teachers of statistics through the establishment of a virtual community of practice. It incorporates both pedagogical and technical considerations (e.g. limitations in terms of equipment, software, protocols, and network bandwidth) regarding delivery of online professional development. It

takes into account technological, but also sociability issues that are important in establishing functional online communities (Barab et al., 2001b). The pedagogical framework will be revised based on knowledge gained through the pilot delivery of the professional development course and will be made available to the public. Online professional development designers and instructors in the field of statistics education will be able to benefit from access to this framework. The framework could also serve as a model for professional development programs in other content areas of mathematics and science.

2.3.4 Project information base

At the end of the project, final revisions and enhancements to the information base content and services will be made, and it will then be opened to all interested teachers and teacher educators. The information base will include:

- A hypertextbook with the material, resources, and activities of the professional development course to be used as a self-paced course, in a facilitated online mode, or as part or all of the material used in a face-to-face course or workshop;
- Technologically enhanced curricular and instructional materials for the teaching and learning of statistics in elementary and middle school;
- A Video Case Library containing segments of real teaching episodes, obtained in the classrooms of the teachers participating in the project, representing the landscape of practice in statistics instruction in Europe, for use by pre-service and in-service teachers and by teacher educators;
- A database containing Student Work Samples developed through contributions of participating teachers, providing examples of good practice in European schools that could also be used in teacher preparation and professional development programs;
- Reports and articles developed through the project;
- Links to statistics education resources available on the Internet;
- Collaboration tools for professional dialogue and support (e.g. email, chat rooms, discussion forums).

The information base will target long-term sustainability and maximum dissemination of innovative statistics curricula and teaching practices in different cultural contexts through supporting multilingual interfaces, transnational collaboration of teachers, and accumulation of collective knowledge from end-users. The system will provide a virtual space where European teachers of statistics with a broad range of experiences and expertise will come together to reflect upon pedagogical theory and practice, to exchange ideas and resources, and to build collaborations. It is expected that a network of education practitioners will be formed which will attract knowledge from teachers, but also from trainers and experts in the area of statistics education. The objective is that, after the end of the project, the information base will continue to be enriched by users that find added value in visiting the website for information and in publishing their experiences for other users to take advantage of new developments.

3. DISCUSSION

Over the past decade, a number of teacher educators have grown dissatisfied with traditional, individualistic, approaches to teacher professional development (Barab et al., 2002). They have come to recognise that for teacher professional development to become more effective in producing real changes in classroom practices, it ought to adopt new pedagogical models that foster a culture of sharing and sustained support for teachers (Guskey and Huberman, 1995; Barab et al., 2001b). Currently, most teachers suffer from professional isolation and have very limited opportunities for collegial interactions and exchanges (Zern, 2002). In order for them to become more successful in implementing reform, they should be afforded opportunities to engage in collaborative learning communities in which they can exchange ideas with other teachers and garner support as they try new strategies in their classrooms (Cochran-Smith and Lytle, 1999; Barab et al., 2002). EarlyStatistics aims to enrich European children's learning of statistics by offering their teachers a high-quality professional development program that seamlessly combines best pedagogical practices in statistics education, adult education, and distance learning. Contemporary visions of web-based instruction and computer-mediated communication which support more participatory and collaborative models of education (Barab and Duffy, 2000; Barab et al. 2001b) guide the program design. The strategies employed include open-ended investigations, use of real-data, simulations, visualisations, collaboration and reflection on one's own and on others' ideas and experiences. Particular care is

being taken to build on teachers' knowledge and experiences and to promote interactive learning and cross-cultural exchange of experiences and ideas. The ideas of collaboration and reflection, and of inquiry and exploration as processes of knowledge construction (Ponte, 2001), underpin the program's design.

A central conviction underlying the design of EarlyStatistics is that learning is a social act best supported through collaborative activities (Vygotsky, 1978). While the project employs innovative technological tools and resources to support educationally useful human-computer interactions, its focus is on exploiting technology to support human-human interactions (Barab et al., 2001a). It is envisaged that teachers participating in the program will form a self-sustaining online community of practice within which they will improve their content and pedagogical knowledge of statistics through connecting and learning from each other in ways that would not have been possible in a more traditional, face-to-face professional development program. This virtual network of practitioners will be the main source for the publication of additional information on experiences and good practices in statistics instruction. The project outputs and services will be useful not only to teachers, but also to academic experts in statistics education, to national and European Education boards, to teacher training institutions, and to designers of online professional development programs. Academic experts and material developers will get more sensitised to the needs of statistics teachers in different countries, supporting the development of new professional development methodologies and materials grounded in a community-building model. Teacher training institutions will gain clearer understanding of the issues facing statistics teaching and learning and will be able to utilise the project outputs for further improvement of their teacher preparation programs. Online professional development designers will benefit from access to a pedagogical framework for effective professional development in statistics education via the emergence of an online space designed to support teachers in sharing and evolving their teaching practices. The ultimate beneficiaries will be students, who will eventually benefit from improved from improved curricula and teaching practices.

Maria Meletiou-Mavrotheris is an Assistant Professor in the Education Department of Cyprus College. She earned, from the University of Texas at Austin, the degrees of B.A. in Mathematics (1993), M.Sc. in Statistics (1994), M.Sc. in Engineering (1998), and Ph.D. in Mathematics Education (2000). Her research interests focus on the study of issues related to the teaching and learning of statistics, and particularly on the design, implementation, and evaluation of innovative educational technologies. She has been able to obtain considerable funding in support of her research from agencies in Cyprus, the European Union, and the US.

Efstathios Mavrotheris is a Research Associate at the School of Computer Science and Engineering of Cyprus College. He holds a B.Sc. in Computer Science (1986), a B.A. in Economics (1987), an M.Sc. in Computer Science (1990), and MBA/MPSM (expected 2007). His research interests focus on technology enabled education, and particularly on the design and implementation of ICT applications for teaching Mathematics, Statistics, and Science. He has been able to obtain considerable funding in support of his research from agencies in Cyprus, the European Union, and the US.

References

Bakker, A. (2003) 'Reasoning about Shape as a Pattern in Variability', in Lee, C. (Ed), *Reasoning about Variability: A Collection of Current Research Studies* [On CD], Dordrecht, the Netherlands: Kluwer Academic Publisher.

Barab, S. A. and Duffy, T. (2000) 'From Practice Fields to Communities of Practice', in Jonassen, D. and Land, S. M. (Eds.) *Theoretical Foundations of Learning Environments* (pp. 25-56), Mahwah, NJ: Lawrence Erlbaum Associates.

Barab, S.A., Barnet, M. and Squire, K. (2002) 'Developing an Empirical Account of a Community of Practice: Characterising the Essential Tensions', *The Journal of the Learning Sciences,* vol. 11, no. 4, pp. 489-542.

Barab, S. A., Thomas, M. T. and Merrill, H. (2001a) 'Online Learning: From Information Dissemination to Fostering Collaboration', *Journal of Interactive Learning Research*, vol. 12, no. 1, pp. 105-143.

Barab, S.A., Makinster, J.G., Moore, J.A. and Cunningham, D.J. (2001b) 'Designing and Building an On-line Community: The Struggle to Support Sociability in the Inquiry Learning Forum', *Educational Technology Research and Development,* vol. 49, no. 4, pp. 71–96.

Begg, A. and Edwards, R. (1999) *Teachers' Ideas about Teaching Statistics,* Paper presented at the Joint Conference of the AARE and NZARE, Melbourne.

Carnel, L. J. (1997) 'Computers in Probability Education', in Kapadia, R. and Borovcnik, M. (Eds.), *Chance Encounters: Probability in Education*, (pp. 169-211), Boston: Kluwer Academic Publishers.

Cochran-Smith, M. and Lytle, S. L. (1999) 'Relationships of Knowledge and Practice: Teacher Learning in Communities', in Iran-Nejad, A. and Pearson, P. D. (Eds.), *Review of Research in Education* (pp. 249–305), Washington, DC: American Educational Research Association.

Collis, B. and Moonen, J. (2001) *Flexible Learning in a Digital World: Experiences and Expectation*s, London: Kogan Page.

Finzer, W. (1999) *Fathom,* [Software] (1993), Berkeley, CA: Key Curriculum Press.

Fischbein, E. (1975) *The Intuitive Sources of Probabilistic Thinking in Children*, Dordrecht, The Netherlands: Reidel.

Frykholm, J. (1999) 'The Impact of Reform: Challenges for Mathematics Teacher Preparation', *Journal of Mathematics Teacher Education*, vol. 2, pp. 79-105.

GAISE College Report (2005) *Guidelines for assessment and instruction in statistics education*, The American Statistical Association, [Online], Available: [http://www.amstat.org/education/gaise] (accessed December 2006).

Gould R and Peck R (2004*) Preparing secondary mathematics educators to teach statistics.* Paper presented at the International Association for Statistical Education 2004 Roundtable, Lund, Sweden; 28 June–3 July.

Gray, B. (2004) 'Informal Learning in an Online Community of Practice', *Journal of Distance Education*, vol. 19, no. 1, pp. 20-35.

Guskey, T.R. and Huberman, M. (Eds.) (1995) *Professional Development in Education: New Paradigms and Practices,* New York: Teachers College.

Hammerman, J., and Rubin, A. (2003) 'Reasoning in the Presence of Variability', in Lee, C. (Ed), *Reasoning about Variability: A Collection of Current Research Studies* [On CD], Dordrecht, the Netherlands: Kluwer Academic Publisher.

Hirsch, L and O' Donnell, A. (2001) 'Representativeness in Statistical Reasoning: Identifying and assessing misconceptions', *Journal of Statistics Education*, vol. 9, no. 2, [Online], Available: [http://www.amstat.org/publications/jse/v9n2/hirsch.html] (accessed December 2006).

Konold, C. (2005) *Tinkerplots*, [Software], University of Massachusetts: Key Curriculum Press.

Lajoie, S. and Romberg, T. (1998) 'Identifying an Agenda for Statistics Instruction and Assessment in K-12', in Lajoie, S. (Ed.), *Reflections on Statistics: Learning, Teaching, and Assessment in Grades K-12,* (pp. xi-xxi), Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

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

Lisbon Summit (2000, March) Conclusions of the Lisbon Summit, [Online], Available: [http://ue.eu.int/summ.htm] (accessed August 2005).

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

Meletiou-Mavrotheris, M. (2003) 'Technological Tools in the Introductory Statistics Classroom: Effects on Student Understanding of Inferential Statistics', *International Journal of Computers for Mathematical Learning*, vol. 8, no. 3, pp. 265-297.

Meletiou-Mavrotheris, M. and Lee, C. (2002) 'Teaching Students the Stochastic Nature of Statistical Concepts in an Introductory Statistics Course', *Statistics Education Research Journal,* vol. 1, no. 2, pp. 22-37.

Meletiou-Mavrotheris, M. and Stylianou, D. (2003) 'On the Formalist View of Mathematics: Impact on Statistics Instruction and Learning' *Proceedings of the Third Conference of the European Society for Research in Mathematics Education*, [Online], Available: [http://www.dm.unipi.it/~didattica/CERME3/proceedings/Groups/TG5/TG5_meletiou_cerme3.pdf] (accessed December 2006).

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

National Research Council. (2000) *How people learn: Brain, mind, experience, and school*, Washington, DC: National Academy Press.

Nicholson, J. R. and 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.

Paparistodemou, E. and Noss, R. (2004) 'Designing for Local and Global Meanings of randomness', *Proceedings of the Twentieth Eighth Annual Conference of the International Group for the Psychology of Mathematics Education*, Bergen, Norway, Vol.3, p.p. 497-504.

Ponte, J. P. (2001) 'Investigating in Mathematics and in Learning to Teach Mathematics', in Lin, F. L. and Cooney, T J. (Eds.), *Making Sense of Mathematics Teacher Education* (pp. 53-72), Dordrecht: Kluwer.

Pratt, D. C. (1998) *The Construction of Meanings In and For a Stochastic Domain of Abstraction*, Ph.D. Thesis, University of London.

Rossman, A., Medina, E., and Chance, B. (2006) 'A Post-Calculus Introduction to Statistics for Future Secondary Teachers', Proceedings of the 7th International Conference on Teaching Statistics, Salvador, Brazil, [Online], Available: [http://www.stat.auckland.ac.nz/ ~iase/publications/17/2E2_ROSS.pdf] (accessed December 2006).

Rubin, A. (2002) 'Interactive Visualisations of Statistical Relationships: What Do We Gain?', Proceedings of the Sixth International Conference on Teaching Statistics [CD-ROM], Durban, South Africa.

Shamatha, J. H., Peressini, D., and Meymaris, K. (2004) 'Technology-supported mathematics activities situated within an effective learning environment theoretical framework', Contemporary Issues in Technology and Teacher Education, vol. 3, no. 4, [Online], Available: [http://www.citejournal.org/vol3/iss4/mathematics/article1.cfm] (accessed December 2006).

Smylie, M. (1995) 'Teacher Learning in the Workplace: Implications for School Reform', in Guskey, T. and Huberman, M. (Eds), Professional *development in Education: New Paradigms and Practices*, New York: Teachers College Press.

Stigler, M. and Hiebert, J. (1999) *The Teaching Ga*p, Free Press.

Tinker, R. and Haavind, S. (1996) 'Netcourses and Netseminars: Current Practice and New Designs', *Journal of Science Education and Technology*, vol. 5, no. 3, pp. 217-223.

Vygotsky, L.S. (1978) *Mind in Society: The Development of Higher Psychological Processes*, Cambridge, MA: Harvard University.

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,* vol. 4, no. 4, pp. 305-337.

Wenger, E. (1998) *Communities of Practice: Leaning, Meaning, and Identity*, Cambridge, UK: Cambridge University Press.

Zern, K. (2002) *TAPPED IN's After School Online Program: Teacher Professional Development on the Internet*, [Online], Available: [http://www.tappedin.org/ tappedin/web/papers/2001/ KimzernPaper.pdf] (accessed December 2006).

