*EARLYSTATISTICS***: A COURSE FOR DEVELOPING TEACHERS' STATISTICS TECHNOLOGICAL AND PEDAGOGICAL CONTENT**

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TITRE

EarlyStatistics : un cours pour développer les connaissances techniques et pédagogiques des professeurs pour enseigner la statistique

ABSTRACT

EarlyStatistics is a professional development course, which aims to enhance the teaching and learning of early statistical reasoning in elementary and middle European schools. This paper describes the *EarlyStatistics* professional development course and it investigates, through content analysis of the course design, how the *EarlyStatistics* course promotes the development of teachers' Statistics Technological and Pedagogical Content Knowledge (STPACK). In this paper, we present teachers' ($n = 9$) perceptions regarding the affordances and constraints that the course provoked for their professional development.

Keywords: *technological, pedagogical, content knowledge, statistical problem solving.*

RÉSUMÉ

EarlyStatistics est un cours de développement professionnel qui a pour but d'améliorer l'enseignement et l'apprentissage des premiers raisonnements statistiques dans les écoles européennes de niveau élémentaire ou moyen. Cet article décrit le cours *EarlyStatistics* et analyse le cadre conceptuel du cours (Statistics Technological and Pedagogical Content Knowledge, STPACK) pour montrer comment il promeut le développement des connaissances techniques et pédagogiques des professeurs pour enseigner la statistique. Nous présentons aussi dans cet article les perceptions de neuf professeurs sur les possibilités et les limites du cours pour leur développement professionnel.

Mots-clés : *technologie, pédagogie, cadre conceptuel, resolution de problèmes statistiques.*

1 Introduction

Enhancing the teaching and learning of early statistics in European Schools is an overarching goal of educational systems throughout Europe. Researchers in the field of statistics education agree that achieving this goal requires teachers to possess thorough understanding of the meaning of statistical literacy, reasoning and thinking, and of the associated statistical problem solving process, to be competent in the use of technological

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tools that promote data exploration and analysis, and to also comprehend the relationship between statistics and probability (Batanero & Díaz, 2011; Eichler, 2008).

But, the reality is that most of the European national curricula are still anchored in traditional "stochastic teaching" frameworks that present statistics and probability as separate sub-domains of mathematics (Ottaviani, 2008). The curricular stochastical proposals for statistics only describe concepts, but do not describe thinking processes that emphasize the analysis of the variability in the data. The conceptual difficulties involved in understanding the nondeterministic nature of the statistical ideas and the variability inherent in all real processes limit the teaching of statistics in the elementary and middle schools levels to basic descriptive statistics. Innovative school curricula tend to present probability as a tool for statistics and as a domain of mathematics that models nondeterministic relationships (Meletiou-Mavrotheris, 2007). On these innovative curricular proposals, developing understanding of the meaning of data variability and variation necessitates an exploratory data analysis approach to statistics (Biehler, 2003), using software such as TinkerPlots or Fathom as investigative tools (Garfield & Ben-Zvi, 2007). Although the use of Information and Communication Technological (ICT) tools could help enhance the development of students' statistical reasoning, actual employment of technology in the classroom is often limited by the fact that teachers feel ill-equipped to deal with "ICT teaching skills" (OECD, 2009; 2011).

Existing research shows that effective teacher preparation is an important factor for successful integration and sustainability of ICT in education (BECTA, 2004; Davis, Preston, & Sahin, 2009; Hennessy *et al.*, 2007). However, attending technology seminars or workshops that focus exclusively on participants' familiarization with the features of specific educational software does not suffice for teachers to build understanding of the possible interactions between the use of particular software and the pedagogies in a specific subject matter (Jimoyiannis, 2010). In fact, traditional teacher training programs, both pre-service and in-service, have not been successful in providing educators with the knowledge and skills necessary for a lifetime of teaching. As a consequence, the European Commission acknowledges the need for providing teachers with opportunities for continuous professional development as a means of enhancing the quality of instruction offered in European schools (European Union, 2010). During the last two decades, the European Union has stimulated and supported various policies that promote teachers' continuous professional development, as well as numerous research programs.

In this paper we will first describe the *EarlyStatistics* professional development course. Then, we investigate, through content analysis of the course design, how the *EarlyStatistics* course promotes the development of teachers' Statistics Technological and Pedagogical Content Knowledge (STPACK). We also present some results about the perceptions of *EarlyStatistics* participants regarding the affordances and constraints that the course provoked for their professional development.

2 *EarlyStatistics*: A teacher professional development course

EarlyStatistics, *Enhancing the Teaching and Learning of Early Statistical Reasoning in European Schools*, was a Socrates-Comenius project (Ref. No: 226573-CP-1-2005-1-CY-COMENIUSC21, 2005-2008). The main outcome of the project was the design of a teacher professional development course in statistics education targeting elementary and middle school teachers (ages 6-15).

The conceptual "Framework for Teaching Statistics within the K-12 Mathematics Curriculum" GAISE (Franklin *et al.*, 2007) has been used to structure the presentation of content in the *EarlyStatistics* course. Statistics is presented 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) analysing the data by selecting appropriate graphical or numerical methods; and (iv) interpreting the results.

The *EarlyStatistics* course has a hybrid format that combines a weeklong face-to-face Intensive Seminar (48 hours in total), with an e-learning component delivered using the project online learning environment. In Session 1 of the Intensive Seminar, teachers are introduced to the objectives and pedagogical framework underlying *EarlyStatistics* and are familiarised with the facilities offered by the e-learning environment. In Sessions 2-5, they take part in authentic educational activities which give them the opportunity to reflect on the "big ideas" of statistics and their applications, and to explore ways of improving statistics instruction through the adoption of a coherent technology-rich curriculum based on the statistical problem solving process. Teachers analyse several well-constructed, technology-enhanced teaching scenarios that promote statistical reasoning and thinking, and are then asked to develop their own scenario. They implement this scenario in a follow-up classroom experimentation, taking place during the second online part of the course.

The course aims to enhance the quality of statistics education offered in European schools through improving mathematics teachers' technological, pedagogical and content knowledge of statistics. In the next section we present our proposal for the Statistics Technological Pedagogical Content Knowledge (STPACK) framework.

3 Statistics Technological Pedagogical Content Knowledge (STPACK)

The pedagogical framework guiding *EarlyStatistics* is the Statistics Technological Pedagogical Content Knowledge (STPACK), a model for statistics teachers' professional development built based on the Technological Pedagogical Content Knowledge (TPACK) and the Technological-Pedagogical Statistical Knowledge (TPSK) conceptual frameworks.

The Technological Pedagogical Content Knowledge (TPACK) conceptual framework was developed based upon the advanced idea of *Pedagogical Content Knowledge* (PCK), introduced by Shulman (1987), which represents the blending of content and pedagogy into an understanding of how particular aspects of subject matter are organized, adapted, and represented for instruction.

In recent years, the mathematics education community has begun to fill a serious gap in the research literature by increasing both the volume and quality of conducted research related to teachers' pedagogical content knowledge (PCK) of mathematics. Hill, Ball, & Schilling (2008) have extended PCK to describe the mathematical knowledge needed for teaching, distinguishing between common and specialized content knowledge. Schoenfeld & Kilpatrick (2008) offer a provisional framework for proficiency in teaching mathematics that includes, among others, knowledge of students as thinkers and knowledge of students as learners. The cognitive component (students' learning) is one of the key elements in the didactical analysis of teaching and learning processes, along with the epistemic component (mathematical

content). From an anthropological and semiotic perspective, the epistemological component, the cognitive component, and the instructional component make up the three dimensions of mathematical knowledge and knowledge of teaching/learning (Godino, Batanero, & Font, 2007). On the integration of these three dimensions, teaching and learning processes can be analysed considering mathematical or statistical actions that students carry out to solve problems posed, as well as actions carried out by teachers to promote learning and contextualization of content.

In the field of statistics, the epistemological and cognitive component has been the foreground of components introduced for assessing the PCK that teachers need to be able to anticipate the range of students' likely answers to questions and to respond in ways that further develop students' understanding (Watson & Nathan, 2010). Burgess (2006) developed a framework for teacher knowledge in relation to statistical thinking, which was employed in their study to examine teacher knowledge needed and/or actually used for teaching statistics through investigations. The framework was used to map teachers' knowledge while teaching statistics in relation to the six components of statistical thinking in Wild and Pfannkuch's (1999) model: engaging in statistical thinking, recognizing need for data, transnumerating, considering variation, reasoning with statistical models, integrating the context. Lee and Hollebrands (2011) consider these six components as the statistical knowledge (SK) needed by teachers to be able to engage in statistical thinking.

In describing PCK and SK, we made no reference to teacher knowledge of technology. The fact is that when Shulman (1986) introduced his PCK model, information and communication technologies were by no means as widespread as they are today, and did not offer affordances with the potential to change the nature of teaching and learning. Nowadays, however, though not all teachers have embraced the use of new technologies, knowledge of technology has become an important aspect of overall teacher knowledge (Mishra & Koehler, 2006). Mishra and Koehler (2006), the authors of TPACK, have developed a framework that helps to comprehend the new needs of teachers' knowledge using technology through the description of the connections, interactions, affordances, and constraints between and among content, pedagogy and technology.

Mishra and Koehler's (2006) model, which was originally named TPCK, but is now known as TPACK, allows teachers, researchers and teacher educators to move beyond oversimplified approaches that treat technology as an "add-on", but instead to focus upon the connections among technology, content, and pedagogy as they play out in classroom contexts (Koehler & Mishra, 2009). The model defines PCK in a consistent and similar manner to Shulman's idea of knowledge of pedagogy and content. It also characterizes other knowledge, as: (a) technological content knowledge (TCK), and (b) technological pedagogical knowledge (TPK). The intersection of these three elements (PCK, TCK and TPK) leads to technological pedagogical content knowledge (TPACK) (Koehler & Mishra, 2009; Mishra & Koehler, 2006).

These seven constructs capture the different types of teacher professional expertise needed for effective technology integration (Chai, Koh, Tsai, & Tan, 2011). TPACK has been embraced as a theoretical basis for structuring ICT curriculum in teacher education programs (Angeli & Valanides, 2009) and for researching how teachers acquire it (Cox & Graham, 2009). Research indicates that mathematics teachers' participation in continuous professional development programs plays a crucial role in whether and how they integrate TPACK (Bennison & Goos, 2010; Doukakis, *et al.*, 2010; Meng & Sam, 2013; Shafer, 2012).

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In the case of statistics, Lee & Hollebrands (2011) distinguish between two bodies of research on the use of technology in statistics. The first body of research involves studies that have investigated the ways in which the teaching and learning of statistics has been influenced by technology. The second body of research involves studies which, while also examining how technology might influence statistics teaching and learning, have also included descriptions of the required technological and pedagogical content knowledge for the effective integration of technology in statistics instruction. Lee & Hollebrands (2011) have characterized the important aspects of knowledge needed to teach statistics with technology, and have developed a Technological Pedagogical Statistical Knowledge (TPSK) framework that integrates: (a) the six components of the Statistical Knowledge (SK) in the Wild and Pfannkuch (1999) model; (b) understanding of how to use technology to explore statistical ideas; and (c) understanding of pedagogical issues related to teaching statistics.

The development of TPSK is conceptualised as three layered circles. The largest one is teachers' statistical knowledge (SK), inside of which lies the Technological Statistical Knowledge (TSK), while the inner circle represents the elements of TPSK. TPSK is described as: (a) understanding students' learning and thinking of statistical ideas; (b) having a conception of how technology tools and representations support statistical thinking; (c) having knowledge about and practice in using instructional strategies for developing statistics lessons with technology; (d) taking a critical stance towards the evaluation and use of curricula materials for teaching statistical ideas with technology (Lee & Hollebrands, 2011). For the authors of the TPSK framework, developing TSK and SK is essential to, but not sufficient for teachers to have specialised TPSK. We hypothesise that this may be due to the fact that they do not take into consideration the integration of other elements of the TPACK construct that are key for teaching statistics.

Although initially the characterization of the TPACK was a list of examples without consistent definitions (Graeber & Tirosh, 2008), research on its characterization has provided succinct explanations of the seven elements of the construct (Cox & Graham, 2009; Mishra & Koehler, 2006; Shulman, 1987). In developing the Statistics Technological Pedagogical and Content Knowledge (STPACK) model used in the current study, we drew on this research, and we also integrated the list of definitions developed by Burgess (2006), Hill, Ball, and Schilling (2008), Lee and Hollebrands (2011), Watson and Nathan (2010), and Jimoyiannis (2010).

Statistics Technological Pedagogical and Content Knowledge (STPACK) indicators, which are included in the Annex, were determined prior to the conduct of the case study presented in the next section.

4 Methodology

The study presented in this paper had three objectives: (a) developing the Statistical Technological Pedagogical and Content Knowledge (STPACK) framework, included in Section 8 (Annex); (b) applying this theoretical framework to a case study of the STPACK curricular dimensions of the *EarlyStatistics* course organization and tasks; and (c) analysing teachers' perceptions about the affordances and constraints that their participation in the course provoked for their professional development.

The first part of the case study consisted of content analysis of the STPACK curricular dimensions and the related *EarlyStatistics* tasks. The content of all tasks included in the

EarlyStatistics professional course was analysed using the STPACK indicators. Each task was codified based on the Statistical Problem Solving process involved, and in relation to the seven constructs of the STPACK.

The second part of the case study consisted in the analysis of teachers' perceptions. Nine in-service teachers (7 females, 2 males), originating from five different European countries (Cyprus, Greece, Ireland, Spain and Turkey) participated in the case study. Five of the participants were elementary school teachers, and four were secondary school mathematics teachers. Multiple techniques were used to collect data and document changes in teachers' technological pedagogical content knowledge of statistics. In this paper, our findings are mainly based on the analysis of a pre-study and a post-study survey. The pre-study survey, administered at the beginning of the course, gathered basic information regarding the participants' background: previous experience in using e-learning tools, participation in technological development courses, etc. The post-study survey examined teachers' perceptions about the affordances and/or constraints of the course in building their STPACK. Each answer was codified in relation to: (a) the statistical problem solving process described; (b) the representation of the STPACK model; and (c) the affordances or constraints expressed by teachers regarding their possible professional development.

5 Results and Discussion

First, we present the results of the content analysis of the intended curriculum of the *EarlyStatistics* professional development course, which targets in-service elementary and middle school European teachers. Next, we describe the perceptions of participating teachers ($n = 9$) in relation to the curricular dimension analysed, considering the information obtained from the pre-survey questionnaire, which provided us baseline information about the teachers' background.

Only two of the teachers had some experience with e-learning prior to their participation in *EarlyStatistics*. Most of the participants did have some previous experience in completing online surveys, but none of them had previously designed one for personal or educational purposes. Only three of the teachers – Marianna, a Cypriot Primary School teacher, Gloria and Rosa, two Spanish Secondary School teachers – had some previous experience in teaching statistics, but had never made use of technology in their class. Justin, a novice Irish Secondary School teacher who had a Bachelor's in Physics, had never taken a formal college-level Statistics Course. Primary School teachers' learning of statistics while at college had been integrated in the mathematics methods course they had taken. For all of the participating teachers, this was the first opportunity they had to participate in a statistics professional development program.

The professional development course described earlier has been organized around the Statistical Problem Solving Process in four different sessions: (i) statistical problem posing; (ii) collecting data; (iii) analysing data; and (iv) interpreting the results and drawing conclusions. The proposal of tasks for each session has been codified using the STPACK model. This coding scheme allowed us to investigate how the tasks could give the opportunity to the teachers of integrating the STPACK. Furthermore, it provided information about the possible obstacles teachers might face when planning their intended curriculum for elementary and middle school mathematics. These challenges and obstacles are contrasted with teachers' perceptions about the enacted curriculum.

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5.1 Clarifying the problem at hand and formulating questions

The statistical problem posing session was organized around four tasks, which aimed at the following: (1) review of literature on mathematical and statistical problem posing and solving; (2) reflection about the epistemological aspects and curriculum proposals; (3) exploration of scenarios related with statistical problem solving developed by the *EarlyStatistics* team (http://www.*EarlyStatistics*.net/?page=scenarios); and (4) planning of a teaching experiment.

In the first task, teachers were asked to review Level A and Level B of the GAISE framework (Franklin *et al.*, 2007), and Nitko & Lane's (1990) research paper. Both documents discuss the differences between mathematical and statistical problem posing and solving, and ways in which the mathematics curriculum can help to promote statistical problem solving. The readings should allow teachers to reflect about the epistemological aspects and curriculum proposals of the documents and to answer these questions:

Task	Questions to discuss about	STPACK
(1)	Which are the differences between mathematical and statistical problem solving?	SPCK3 SPCK4
	Which problems can be treated statistically?	SK6
	Which are the phases of problem solving?	SPCK20
	In problem solving, are there any levels of development of this skill?	SPCK2
	How is problem solving interpreted internationally?	SPCK1
	The GAISE Report describes different levels on developing statistical problem solving and posing strategies. Why and how is the development of these levels conditioned upon the growth of understanding regarding the nature of variation, sampling, chance and randomness?	SPCK2
	Which is the relationship between statistical problem solving, problem posing and thinking statistically?	SK1

These questions aim at promoting in teachers the need to connect problem solving, problem posing and thinking statistically as the common content knowledge that differs from the traditional content knowledge typically included in European Curricula (Batanero & Díaz, 2011). Furthermore, the analysis of the GAISE Report allows teachers to reflect on important statistical ideas they had never formally studied, such as the nature of variation, sampling and chance. In the words of a teacher participating in the course: *"EarlyStatistics allows us to reflect about the statistical ideas we want to work with in the class"* (Gloria, Expert Upper Secondary Spanish teacher). We interpret the words of the teacher as the possibility of her understanding the boarder set of statistical ideas to which a particular idea connects, and how this helps her to design instruction. This understanding, in turn, provides the teacher with the chance of integrating the epistemological, cognitive and instructional components of statistical knowledge, as expressed by Godino *et al.* (2007), and included in the SPCK framework.

Through this possible process of connecting problem solving and thinking statistically (SPCK21), teachers should develop habits of consideration of how to best obtain meaningful

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and relevant data to answer the question posed at hand, as well as understanding of the constant relation of the data to the context of the problem (Chance, 2002). To encourage teachers to reflect about the relation between data and problem context, we asked them in Task 2 to review and discuss some innovative and investigative scenarios developed by the *EarlyStatistics* team on how to introduce statistical problem solving in mathematics classrooms:

Task	Questions to discuss about	STPACK
(2)	Which is the real problem behind these scenarios?	SK6
	How is statistical problem solving introduced in each scenario?	SPCK4
	Which instructional strategies are proposed in this scenario?	SPCK19

The questions proposed in Task 1 should allow teachers to interconnect their pedagogical knowledge (PK) and statistical knowledge (SK) to integrate the pedagogical content knowledge (SPCK) about the general purposes of Statistics Education, the levels of the statistical development process, problem solving processes, and pedagogical strategies to introduce statistical problem solving. Teachers are encouraged to build connections between the theory introduced in Task 1, and the didactical proposals analysed in Task 2. These connections should help them to reflect about their practical decisions on how to introduce statistics and probability problem solving and posing in their classroom. Then, in Task 3, teachers are asked to apply their pedagogical content knowledge by choosing a set of problems related with statistical knowledge that would be interesting and appropriate for their grade level students.

Task	Questions to discuss about	STPACK
(3)	Decide on a topic that you think would be of interest to students of your grade level.	SPCK9
	Formulate one or more questions that would be appropriate for your grade level, and that could be addressed by collecting and analysing data.	SPCK4

5.2 Designing and employing a plan to collect appropriate data

The discussion about data collection was organized around six tasks which aimed at the following: (1) refreshing some statistical concepts on sampling; (2) analysing the role of sample size; (3) reviewing relevant literature on sampling and on the role of sampling methods and sampling size in inferential statistics; (4) reviewing one of the provided scenarios on sampling issues; (5) planning for real data collection; and (6) comparing national school curricula.

5.2.1 Reasoning about sampling methods and sample size

Refreshing some Statistical Concepts on Sampling and analysing the role of sample size was done through asking teachers to reflect on different sampling scenarios developed by Jacobs (1997) and Watson and Moritz (2000). After reading, and discussing the scenarios, teachers were asked to discuss the following questions:

－ What types of sampling methods were employed in the scenarios?

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– What are the pros and cons of the different types of sampling techniques?
– What is the standard type of sampling method employed in statistical studies?
– What is a random probability sample?
– How does sample size affect the results of sample surveys?
– Why are large samples preferable?
– Which are the factors that determine a study's required sample size?

This part of the session concludes by summarizing some important theoretical notions about sampling methods. Furthermore, it gives teachers the chance to reason about the interactions between developing the concepts of sampling and statistical inference (Watson and Moritz, 2000). When reasoning about these interactions, teachers are able to reflect about the knowledge of concepts, theories, ideas and explanatory and organizational frameworks that connect ideas.

5.2.2 Planning for data collection

In Task 4, teachers are asked to articulate the theoretical knowledge about data collection by designing the phase of data collection of their own scenario.

Task	Questions to discuss about	STPACK
(4)	Choose a method of data collection that will be appropriate to use for gathering information to address the question(s) you posed in Session 1.	SK1, 2
	Devise a plan for collecting data: What will you measure? How will you measure it? How many subjects will you include in your study? How will you choose those subjects? Are there any practical considerations and/or limitations?	SK2 SK4
	Make predictions as to what you expect to see in the data.	SK1

Task 4 gives teachers the opportunity to integrate aspects of the Statistical Content Knowledge (SK). They can engage in statistical thinking when they are asked to make predictions about what they expect to see in the data to be collected for the scenario they have designed. In making their predictions, teachers are encouraged to make some informal statistical inferences about the data to be collected, that can help them to reason about the connection between sampling and statistical inference, as proposed by Watson and Moritz (2000). This process also highlights the difficulties that students have in understanding and using statistical inference that include building a scheme of many interrelated ideas such as representativeness, sampling variability and distribution (Saldanha & Thompson, 2003).

These reflections on sampling methods and sample size should help teachers to develop their Content Knowledge (Shulman, 1987), and the distinguished categories introduced by Hill, Ball and Schilling (2008), the Common and Specialised content knowledge. In this context, the Common content knowledge should be the notions of sampling and sample size, and the specialized knowledge should be representativeness, sampling variability, and informal and formal statistical inference. Teachers describe these possibilities when reflecting about the insights that *EarlyStatistics* has given them: *"The course is innovative because it introduces sampling and inference in the early ages"* (Angela, Novice Elementary Primary School Cypriot Teacher). The connection of both concepts, sampling and inference, in the same sentence, can be interpreted as a recognition of a need for data (SK2) when integrating

the context (SK6) to engage in statistical thinking (SK1), and the possibilities to split between different moments of the investigative circle. Furthermore, the teacher can have the opportunity of connecting the two dimensions of the classroom-based investigation, included in Burger's (2006) teacher knowledge framework.

However, the proposal is still disconnected from the pedagogical aspects related to sampling issues. Integration with the pedagogical aspects is done in the second part of the session, and specifically, in Tasks 5 and 6.

5.2.3 Pedagogical knowledge to help students connect the data collection process with the general process of statistical enquiry

Two tasks were included to help teachers integrate the Pedagogical Content Knowledge (PCK) related to data collection: (5) reviewing one of the provided scenarios; and (6) reviewing national school curricula.

Task	Questions to discuss about	STPACK
(5)	Which data collection methods are used in the Scenario?	SK2
	Which instructional strategies does the Scenario employ to help students build their reasoning about the process of data collection? How effective do you consider such strategies?	SPCK11
	Which data collections methods do you think it might be appropriate to introduce to your students? Why?	SPCK11
	Would you adopt this Scenario in your instruction to help your students build their understanding of data collection issues? Why or why not?	SPCK20
	Are there any difficulties that you anticipate you might experience in trying to implement this Scenario in your classroom?	SPCK7, 8,9

The different questions of the task prompt teachers to first analyse the theoretical issues of data collection present in the selected scenario. Later, teachers can reflect on how the scenario promotes reasoning about the data collection process when students are involved in experimental practical work (SPCK11) and constructivist approaches (SPCK20) as an alternative to traditional statistical teaching strategies, key when developing the Pedagogical Content Knowledge (PCK) as described by Jimoyiannis (2010) or Knowledge of Content and Teaching (KCT) as described by Hill, Ball, & Schilling (2008). The last question of Task 5, should allow the teacher to develop the SPCK required to be able to anticipate the range of students' likely answers, in the sense of Watson and Nathan (2010). And, later to reflect about the content-related misconceptions about sampling techniques and sample size, as proposed by Mishra and Koehler (2006). The different questions should let teachers to reflect about the challenge of introducing sampling in their curricula, as can be observed in Task 6.

Task	Questions to discuss about	STPACK
(6)	Review the GAISE Framework Guidelines for levels A and B. Write a short essay addressing the following questions:	SPCK2
	In Australia, the mathematics curriculum calls for the foundations of statistical inference to be laid in the upper primary school years,	

by providing experiences to enable students to "understand what samples are, select appropriate samples from specific groups and draw informal inferences from data collected". In the United States, similar expectations are expressed in the National Council of Teachers of Mathematics Standards (NCTM, 2000), and in the GAISE Framework. How do these expectations compare to your national mathematics curriculum expectations regarding statistical concepts?	
How do you currently approach the topic of data collection in your own mathematics class? How does this differ from the recommendations included in the GAISE Framework and in the articles we reviewed in the Module?	SPCK1
Choose a lesson or activity in your current curriculum. If you were to use this lesson or activity now, how would you modify or extend it to bring out more of the important ideas about data collection?	SPCK20, 21

The last question in Task 6 should help teachers to forge links and connections among different content-based ideas through the data collection and exploration of alternative ways of looking at the same conceptual idea or problem, and should improve their knowledge of the written, intended and enacted curriculum. Teachers participating in *EarlyStatistics* did recognize the importance of reflecting about the knowledge of the curriculum: *"Getting to know the pedagogical aspects of teaching statistics has been very interesting for me. I had never seriously thought about some aspects of statistics learning, and I believe I can improve the way I teach statistics in the future"* (Rosa, Expert Upper Secondary Spanish Teacher). To improve the way they teach statistics, Rosa and the other teachers are encouraged to change their beliefs about the nature of data analysis, and to develop the epistemic component of the SPCK as expressed by Godino *et al.* (2007).

5.3 Analysing the data by selecting appropriate graphical or numerical methods

Understanding the nature of data analysis and the implications for teaching statistics was promoted, as in the other sessions, through involving teachers in five different tasks. Following a similar structure with the one used in the other sessions, tasks in Session 3 included the following: (1) reviewing the literature about data analysis; (2) conducting a theoretical analysis of the evolution of a concept; (3) analysing a scenario; (4) comparing national school curricula with standard-based ones; and (5) engaging in data explorations using educational statistical software.

5.3.1 Exploratory versus descriptive data analysis

As in the other sessions, teachers were asked to read two research articles: "Children's concepts of average and representativeness" of Mokros & Russell (1995) and "Research in the statistics classrooms: Learning from teaching experiments" of Ben-Zvi, Garfield, and Zieffler (2006). The proposed readings were accompanied with the following questions to

help teachers reflect about and discuss the differences between exploratory and descriptive data analysis, and of how technology helps both:

Task	Questions to discuss about	STPACK
(7)	Ben-Zvi and Arcavi (2001) Study (discussed in Ben-Zvi, Garfield, & Zieffler, 2006):	SPCK1
	• Why is global reasoning "fundamental in developing statistical reasoning"?	SPCK11
	• What strategies did the researchers in the Ben-Zvi and Arcavi study employ to encourage students in making the transition from the local to the global view of data?	SPCK19
	• How effective do you consider such strategies?	SPCK21
	• Would you employ them in your classroom?	
	Bakker (2004) Study (discussed in Ben-Zvi, Garfield, & Zieffler, 2006):	SK4
	• Why is coherent reasoning about the ideas of variability and distribution closely related to reasoning about sampling?	
	• One set of activities employed in this study was based on the idea of "growing-a-sample". What were students asked to do in the growing-a-sampling activities? In what way did this help them build their reasoning about sampling?	SPCK8 SPCK14
	• What role did technology play in Bakker's study? How possible would it to include a growing-sample of activities in a statistics classroom that does not have access to technology?	STCK4 STPCK2
	• In Bakker's study, activities "were designed to begin with students' own ideas and guide them towards more conventional notions and representations". How does this differ from standard approaches to statistics in mathematics classrooms?	STPCK4
	Mokros and Russell:	
	• What do the authors mean when they state that "the premature introduction of the algorithm for finding the mean may cause a short circuit in the reasoning of some children?"	STCK1
	• How does the researchers' suggestion differ from standard approaches to the introduction of the mean in mathematics classrooms?	STPCK2
	• One of the main conclusions of Bakker's Study is that statistical concepts should not be introduced and formally defined before students experiment with these concepts and gain an intuitive idea of what the concepts mean and represent. How is this similar to the conclusion drawn by Mokros and Russell regarding the postponement of early introduction of the algorithm for calculating the arithmetic mean?	STPCK3

In order to answer the questions, teachers are asked to reflect about Statistical Knowledge (SK) considering variation and variability. Teachers are also asked to reflect about the general purposes of statistics education, and about students' misconceptions regarding sampling when using constructivist approaches to conceptualize distributions in exploratory data analysis. On

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this proposal, teachers should be able to forge links and connections among different content-based ideas such as sampling, variability and distribution, and to recognize the possibilities that alternative teaching strategies provide to overcome common content-related misconceptions. The forging of these links may help promote the integration of Statistics Pedagogical Content Knowledge (SPCK).

The written and intended curriculum also includes questions that should allow teachers to understand the manner in which statistical content is both positively and negatively influenced by technology (STCK). In the words of Mishra and Koehler (2006), technology is not neutral with regard to its effect upon cognition. An example of this conviction is the use of resources and tools to automate the task of computing statistical measures (e.g., the mean). The use of technology for automating this computation facilitates students' capacity to visualise abstract concepts, and gives them more time to engage in exploratory data analysis. In this sense, Lee and Hollebrands (2011) introduce automation of calculations and representations as an aspect of Technological Statistical Knowledge to be discussed when developing Teachers' TPSK, and conclude that it can help to change the way teachers and students conceptualise statistical measures. The inclusion of technology in our course proved particularly useful for those teachers without an academic background in statistics. Justin, a novice Irish Secondary School teacher, noted for example: *"I benefited a lot from learning some basic theory in Statistical Modelling, Analysis and Interpretation"*.

The last questions in Task 7 go beyond the idea of the use of technology, with the aim of integrating teachers' statistical technological pedagogical and content knowledge through reflection on how technologies can be used to help build new statistical concepts. Teachers are asked to evaluate the instructional tasks included in the studies of Ben-Zvi and Arcadi (2001), and Bakker (2004). Furthermore, the description of the tasks used by Bakker (2004) allows teachers to reflect about appropriate instructional strategies for developing statistics lessons with technology. Teachers also understand in this sense the potentialities of their reflections: *"EarlyStatistics addressed my learning goals because I strongly believe that the students should be able to understand and interpret charts and graphs given to them, but also be able to read between the data and have their own point of view about what is given to them"* (Marianna, expert Middle School Cypriot teacher).

5.3.2 Instructional implications of the ideas related to Data Analysis and Interpretation

In order to reflect on the fact that the studies presented in the previous section promote a pedagogical approach to statistics education that could differ substantially from the aims of national curricula in different European countries, teachers are again asked to compare their national School Curriculum with standard-based curricula (Task 8).

Task	Questions to discuss about	STPACK
(8)	• What is your national curriculum aims regarding data analysis and interpretation at the elementary and middle school level? How do these aims compare with the expectations laid out in the GAISE Framework and the instructional implications offered by Ben-Zvi *et al.* (2006)?	SPCK1
	• How do you currently approach statistics topics related to data analysis and interpretation in your own mathematics class? How	SPCK20

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	does this differ from the recommendations included in the GAISE Framework and in the articles we review in this Module?	
•	Choose a lesson or activity in your current mathematics curriculum. If you were to use this lesson or activity now, how would you modify or extend it to bring out more of the important ideas about data analysis and interpretation?	STPCK7, 8

The selection of questions and its sequence intend to allow teachers an in-depth study of their written National Curriculum and of how it compares to standards-based curricula such as GAISE, and to their traditionally enacted curriculum. Group discussions of the posed questions allowed non-experienced teachers to understand the difficulties involved in addressing the expectations of the traditional curriculum. Angela, a novice Cypriot Primary School teacher, expressed this idea by stating: *"I met people from other E.U. countries and heard about their educational system and their difficulties in implementing their curricula"*. They also gave teachers the opportunity to think about the prospects provided by the integration of technology for enhancing statistics teaching and learning.

Central to the course design is the functional integration of technology and core curricular ideas, and specifically the integration of statistics educational software. The aim of the latter is to stimulate and engage teachers while providing them with the opportunity to model and investigate real-world statistics-related problems.

5.3.3 Data exploration using education statistical software

Teachers participated in two workshops about Tinkerplots that are described in Task 9. In the first workshop teachers worked in solving the statistical problem "Is the New Drug Effective?" (Meletiou-Mavrotheris, 2000). On this proposal we applied an isomorphic approach. The scenario and the educational software Tinkerplots comprise a professional learning environment in which teachers are asked to apply the same knowledge, strategies and competences that they should require from their students (Serradó, Azcárate, & Cardeñoso, 2009). The *EarlyStatistics* course material engages teachers in statistical thinking as doers of statistics. And then it provides them with opportunities to reflect about the affordances and the constraints of technology, and about the ways in which technological tools and representations support data exploration, statistical reasoning and thinking (STPCK3). Research supports the adoption of such an isomorphic approach to teacher professional development, indicating that it can have a positive effect on actual teaching practices (DeGennaro, 2010).

Advancing on the idea of integrating the different aspects of Statistics Technological Pedagogical Content Knowledge, during the second workshop teachers first engaged in data exploration in order to solve "The Yo-Yo Mystery" (Konold, 2009), and then responded to the following questions about instructional implications:

Task	Questions to discuss about	STPACK
(9)	• What statistical concepts and processes could be explored through this activity? • For which grades do you think the Yo-yo Mystery activity is appropriate? Could you adjust the activities to make it suitable for	STCK4 STPACK2 STPACK7

students of lower/upper grades? If yes, explain how you would do that.	
• Where do you think students might encounter difficulties in solving the "Yo-Yo Mystery"? How would you help them to overcome these difficulties?	STPACK1
• Can you think of ways in which you could use this activity to make connections between other subjects that students study at school?	STPACK3

These questions should allow teachers to reflect on students' learning (reasoning and thinking) of statistical ideas through the use of ICT tools (STPACK1), take a critical stance towards the use and evaluation of curricula materials for teaching and learning (STPCK2), and develop understanding of the ways in which technological tools and representations can support statistical thinking and reasoning (STPCK4). These are three of the four descriptors used by Lee and Hollebrands (2011) to describe TPSK, which we have included as descriptors of the STPACK. However, we have also included a reflection about the design (STPACK6), in which teachers should apply their previous knowledge about curriculum (PCK1, 2). On this reflection, the introduction of technology for exploratory data analysis should be considered, as the teachers noted, an innovation that they should integrate into their teaching during the second part of the course (Meletiou-Mavrotheris & Serradó, 2011). In the words of Marianna, an expert Middle School Cypriot teacher: *"the fact that this course is offered now that the mathematics curriculum in Cyprus is changing, is giving me a tool to work more creatively with my students in the future"*. The use of technology by this teacher has provided her with statistical experience that fosters creativity, deepens her conceptual understanding and helps her develop connections that will help her create new curricular designs (Bos, 2011). This experience is not an isolated fact; it is the product of the interactive, communicative and informal capacities of how the technology was used in the course.

5.4 Interpreting the results

In the GAISE Report (Franklin *et al.*, 2007) the fourth component of the statistical problem solving process is interpreting the results of the data analysis, and relating the interpretation to the original question. As a consequence of this interpretation, students should be able to draw data-based conclusions and inferences. With the aim of giving teachers the chance to take a "critical stance towards the use and evaluation of curricula materials for learning statistical ideas with technology" (STPACK2), they were asked to reflect about video cases of teaching episodes. Those teaching episodes took place during the pilot offering of the *EarlyStatistics* course (they can be found in http://www.*EarlyStatistics*.net/?page=teaching_episodes). In order to understand the possibilities that the technology gives when interpreting data-analysis, the two tasks described next were included.

5.4.1 Draw data-based conclusions

Teachers were asked to watch Video Clip 2 (http://www.*EarlyStatistics*.net/?page=video_textSP) of the TV Scenario. This scenario was an adaptation of the TV Scenario developed by the *EarlyStatistics* team (http://www.*EarlyStatistics*.net/?page=scenarios). It was implemented in a second grade

classroom with 25 children (7 year-old). Students participating in the study completed, with their parents' help, a table in which they marked the number of hours they watched TV every day and the kind of programs they were watching. At school, students were asked to codify by colours the programs, and construct bar charts. In the video clip, the teacher asked students to examine the data obtained, comparing the bar charts of each student and writing down their conclusions. Students contrasted the information about each student, distinguishing the mode and anticipating the possible mean values. By watching this video clip, teachers participating in *EarlyStatistics* can observe how children were able, from a critical point of view, to interpret the meaning of TV watching at home and its social implications. The aim is for them to recognize how in this process, students have been involved in transnumeration (Wild & Pfannkuch, 1999) as a process of transforming a representation between a real system and a statistical system with the intention of engendering understanding.

After watching the video clips, teachers were asked to answer two questions: In what ways does the students' involvement with the TV Scenario help them to develop their data analysis skills? How is it connected with the other stages involved in the problem solving process? On this analysis, teachers should be able understand how problem solving processes are useful as a learning strategy (SPCK13). Furthermore, teachers should be able to understand how students engage in transnumeration (SK3). When asked to comment on the usefulness of including videos of teaching episodes in *EarlyStatistics*, all teachers agreed that this was a very helpful activity for highlighting good practices.

5.4.2 Informal statistical inference

The videotaped teaching episode presented here was derived from a study, which aimed at fostering third grade (8 year-old) students' informal notions of inference (http://www.*EarlyStatistics*.net/?page=video_textCY). The students participated in a teaching intervention, which adopted a hands-on, project-based approach to statistics. First, they completed a personal diary about their nutritional, health and safety habits. Then, they decided to compare their habits with those of their classmates. Finally, they started thinking about conducting a survey of students in their school in order to present their results to a school fair at the end of the month. They decided that in order to collect data from all first, second and third grade students in the school, they had to construct a more structured survey. They were also concerned about the large amount of data involved, and about how they would code these data on Tinkerplots data cards. A 16-items questionnaire about gender, age, nutritional habits, health and safety was prepared and administered by the students themselves. The data was then entered into a Tinkerplots database. Next, students employed the features of the dynamical statistics environment to explore and visualize the data, and to formulate and evaluate conjectures based on data. They wrote a report and made a presentation of their findings.

Teachers participating in the course were asked to reflect about two main questions: How do you think young learners begin to reason about informal inference? How can the affordances provided by dynamic learning environment for formulating and justifying data-based inferences, be utilized in the early years of schooling to develop students' statistical reasoning? The discussion of both questions was done through the analysis of excerpts of teaching episodes taking place during the teaching intervention, included in the article "Developing young Students' Informal Inference Skills in Data Analysis" (Paparistodemou & Meletiou-Mavrotheris, 2008). Their discussions gave teachers the chance to integrate different

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components of STPACK: understanding of students' learning (reasoning and thinking) of statistical ideas through the use of ICT tools, a critical stance towards the use and evaluation of curricula materials for teaching and learning statistical ideas with technology, conceptions of how technological tools and representations support statistical thinking and reasoning, effective instructional strategies for the integration of technology in statistics lessons.

The comparison of both tasks gave teachers the challenge of understanding the affordances of integrating the different components of the STPACK. Angela, a Primary Cypriot School Teacher, expressed her feelings as: *"I am much more confident now to teach statistics. The Tinkerplots software, the videos, the surveys we were informed about, as well as the questions, have helped me to understand the basic ideas and issues of Statistics"*. But, for some teachers this was not adequate: *"I was a little surprised that the course was aimed at the lower levels of School Education which meant that less relevant material was covered. However, given my own lack of experience in non-deterministic statistical pedagogy, it was probably good to start near the bottom"* (Justin, a novice Secondary School Irish Teacher). As discussed in more detail in Serradó, Meletiou and Paparistodemou (2013), this teacher suggests the need for an improvement of the *EarlyStatistics* design by including all three levels of the GAISE Framework (Franklin *et al.*, 2007) in the course readings, reflections and discussions. This change would not imply any modification of the course structure, which was well accepted by the teachers: *"The whole course was well organized, and we had the opportunity both to learn and to apply what we learned in field practice"*. (Marianna, Cypriot Primary School teacher). Similarly to Marianna, all the other course participants also expressed their approval of the course module organization. They also all agreed that the use of Moodle, an e-learning platform, for both face-to-face and online instruction, helped to improve understanding of how to best use the interactive instructional tools and resources in statistics teaching and learning.

6 Conclusions and Implications

The four components of the statistical problem solving process are the organizers of the course design. In each of these components, there are three tasks that give continuity to the reflections and discussions of the teachers, and these are: the analysis of the curricular proposals, the analysis of the scenarios designed by the *EarlyStatistics* team, and the planning of their own scenario for a follow-up classroom experimentation. The analysis of the curricular proposals has given teachers the opportunity to familiarize themselves with ways of representing and formulating the subject that make it comprehensible to others, and has thus contributed towards the development of teachers' Pedagogical Content Knowledge of statistics. We agree with Hill, Ball and Schilling (2008) that knowledge of the curriculum is a priority for the professional development of the teacher.

Furthermore, the analysis of the scenarios designed by the *EarlyStatistics* team and the planning of their own scenario have given teachers the opportunity to reflect about the pedagogical, epistemic, and cognitive components of statistics education. We agree with Godino, Batanero, and Font (2007) about the importance of all three components when developing teachers' Statistics Pedagogical Content Knowledge (SPCK). As evidenced in the *EarlyStatistics* course design and expressed by the teachers, those tasks have been essential for forging links and connections among different content-based ideas through the statistical problem solving process.

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The content-based ideas developed through this statistical problem solving process were those fundamental thinking types introduced by Wild & Pfannkuch (1999), and adopted by Lee & Hollebrands (2011) as the external set of the Technological Pedagogical Statistics Knowledge. We also have accepted those fundamental thinking types as the statistical knowledge that organizes and connects key statistical ideas. Using again the categories of Hill, Ball, and Schilling (2008), this could be considered, along with the statistical problem solving process, as the common content knowledge – as described in the section *"Planning data collection"* – that gives teachers the chance to understand the meaning of other specialised statistical concepts such as variability, representativeness, etc.

In the tasks given to teachers during Sessions 1-2 of the course, which concerned the first two processes of the statistical problem solving – clarifying the problem at hand and designing and employing a plan to collect appropriate data – no reference was made to the use of technology. In fact, when the course was first designed and implemented (Meletiou-Mavrotheris & Serradó, 2011), the use of online technologies for collecting data was still at a developmental stage. In the course offering that we present in this paper, we have been using the affordances of Moodle, an e-learning environment, to collect quantitative and qualitative data about the teachers' perceptions. In future offerings of the course, the data-collection tasks could be improved through the inclusion of articles that discuss the use of technological tools for online data collection (e.g., Google drive, Moodle, Survey Monkey, InspireData), reflections on the pedagogical use of educational software for online data collection, analysis of scenarios such as those proposed in the "Census at School project" (http://www.censusatschool.org.uk/), and planning of teachers' own scenario involving the collection of data with the use of the technology.

The next two stages of the statistical problem solving used technology. The tasks included in these two stages had the aim of giving teachers the opportunity to reflect on the differences in learning and teaching with and without technology. In the data analysis process, teachers were asked to integrate their pedagogical content knowledge and technological knowledge in an effort to help them develop their the Statistics Technological Content Knowledge through engaging in being doers of statistics. They were then provided with adequate time to reflect about the affordances and constraints of the software, and the possibilities that it gives for teachers to construct their own conceptions of how technological tools and representations can support data exploration, statistical reasoning and thinking. We used the same instructional strategies as those developed by Lee and Hollebrands (2011). In this sense, the first four indicators of the STPACK framework coincide with those introduced by these authors in the TPSK. We differ in the fact that the aim of the *EarlyStatistics* course is that the teachers plan their own scenario to be developed at school. For this reason, in the STPACK category of the framework we introduced two other items: development of simulations for specific statistical content knowledge learning, and design and development of complete learning scenarios based on statistical investigations using ICT tools. For developing a complete scenario, we think that teachers should reflect during all the stages of the statistical solving problem process about the seven categories of the STPACK framework, through an aggregate view of connecting the knowledge of each category.

These thoughts have been proposed in the design of the course and presented in the results. But, the content analysis has also provided us with useful information about some gaps in the development of the STPACK in the course. We have acknowledged a gap in developing the TPK of the STPACK due to the fact that, in the last two stages of the statistical problem solving process, the teachers act as doers of statistics. Their active

participation in statistical problem solving, encourages teachers to reflect directly about the software used for statistics teaching and learning, without however giving them the opportunity to experience how technology can facilitate, in general, the adoption of pedagogical approaches such as fostering inquiry with ICT (Jimoyiannis, 2010).

Summarizing, in this paper we have presented the Statistics Technological Pedagogical and Content Knowledge (STPACK) framework constructed based on the Technological Pedagogical Content Knowledge (TPACK) and the Technological-Pedagogical Statistical Knowledge (TPSK) conceptual frameworks. We have used the framework for content analysis of the *EarlyStatistics* course design. The course is organized around the statistical problem solving process, involving teachers in reflecting and discussing about the different stages of this process and the specialized content knowledge that emerges out of it. The positive perceptions of teachers participating in the most recent offering of the course regarding the questions posed reflection and discussion, indicates that the course promotes the link between key statistical ideas, and provides teachers with the opportunity to innovate on how they teach statistics, by supporting their professional development and the integration of their STPACK.

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Annex: Statistical Technological Pedagogical and Content Knowledge (STPACK) items

a. Technological Knowledge (TK) – computer literacy required for persons to understand information technology broadly and apply it productively at work and in their everyday life.
b. Pedagogical Knowledge (PK) – deep knowledge about the processes and practices or methods of teaching and learning:
    PK1: Encompassing of educational purposes, values, and aims.
    PK2: Knowledge that applies to student learning, classroom management, lesson plan development and implementation, and student evaluation.
    PK3: Techniques and methods used in the classroom
    PK4: Understanding of the nature and needs of the target audience
    PK5: Strategies for evaluating student understanding
c. Statistics Knowledge (SK) – statistics knowledge as knowledge of explanatory frameworks that organize and connect statistical ideas:
    SK1: Engaging in statistical thinking
    SK2: Recognizing the need for data
    SK3: Transnumerating
    SK4: Considering variation
    SK5: Reasoning with statistical models
    SK6: Integrating the context
d. Statistical Technological Content Knowledge (STCK) – knowledge of how content can be researched or represented by technology (e.g. using computer simulations).
    • Technological Statistical Knowledge
    STCK1: Automation of calculations and representations. Knowledge of resources and tools available for statistics
    STCK2: Operational and technical skills related to data exploration (Tinkerplots, Fathom…)
    STCK3: Visualization of abstract concepts (Dynamic representation of data, simulations of specific statistical knowledge)
    STCK4: Investigations of real data: ICT-based statistical problem solving process, methods of analysing experimental data, modelling and simulation.
    STCK5: Skills in using collaborative Web 2.0 tools
e. Statistical Pedagogical Content Knowledge (SPCK) – knowledge of "the ways of representing and formulating the subject that make it comprehensible to others" (Shulman, 1986, pp. 9):
    • Curriculum:
    SPCK1: General purposes of Statistics Education: literacy, reasoning and thinking.
    SPCK2: Levels of statistical development process
    • Pedagogical epistemic components:
    SPCK3: Nature of Statistics and Probability
    SPCK4: Problem solving processes and statistical investigations
    SPCK5: Determinism versus randomness and variation

SPCK6: Technological-statistical literacies
- Pedagogical cognitive components:

SPCK7: Students' prior mathematical and statistical knowledge

SPCK8: Students' misconceptions about key statistical concepts like variation, variability, sampling, distribution

SPCK9: Students' skills in investigating and inquiring
- Learning strategies:

SPCK10: Statistical dispositions of students

SPCK11: Use of exploratory data analysis strategies

SPCK12: Use of statistical inquiry

SPCK13: Use of statistical interpretation and conclusion, with the aim of drawing inferences

SPCK14: Use of constructivist approaches

SPCK15: Use of cognitive conflict situations

SPCK16: Use of conceptual change strategies
- General pedagogy:

SPCK17: Knowledge of basic pedagogy for teaching statistics

SPCK18: Development of a pedagogical philosophy of learning statistics

SPCK19: Knowledge of pedagogical strategies (exploration data analysis versus descriptive analysis or inferential analysis)

SPCK20: Forging of links and connections among different content-based ideas through statistical problem solving strategies.

SPCK21: Exploration of data analysis as a strategy for looking at the same idea or problem in alternative ways.

SPCK22: Understanding of statistical educational context school culture, statistical educational purposes, statistical practical knowledge, classroom organizational knowledge when developing statistical investigations, etc.

f. Technological Pedagogical Knowledge (TPK) – knowledge of how technology can facilitate pedagogical approaches.
- Affordances of ICT tools:

TPK1: Knowledge of pedagogical affordances of ICT

TPK2: Knowledge and skills to identify pedagogical properties of specific software

TPK3: Knowledge and skills to evaluate educational software

TPK4: Ability to select tools supporting specific learning approaches
- Learning strategies supported by ICT

TPK5: Supporting of experimental practical work

TPK6: Use of constructivist approaches

TPK7: Promotion of student motivation and/or engagement using ICT tools

TPK8: Fostering of cooperative learning
- Fostering statistical inquiry with ICT

TPK9: Use of the statistical inquiry circle in statistical investigations.

TPK10: Ability to go through the statistical problem solving process using ICT tools
- Information skills

TPK11: Search and access of data in digital media (resources such as CENSUS at School, data of the National Statistical Institutes,…)

TPK12: Analysis and evaluation of statistical content in digital mass media
- Student scaffolding

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  TPK13: Recognition and handling of students' learning difficulties when using ICT tools

  TPK14: Promotion of students' conceptual change processes when using ICT tools

  TPK15: Development of cognitive conflict in learners through the use of ICT tools

  TPK16: Student support in developing information skills

  •   Handling of students' technical difficulties

  TPK17: Student support in developing technical and operational skills for specific ICT tools (Fathom, Tinkerplots, Excel, Graphics,)

  TPK18: Student support in using modelling software in exploratory data analysis

  TPK19: Encouragement of student motivation and/or engagement using ICT tools

  TPK20: Fostering of cooperative learning

g. Statistical Technological Pedagogical Content Knowledge (STPACK) – knowledge of ways to facilitate students' learning of different statistical concepts through appropriate pedagogy and technology.

  STPACK1: Understanding of students' learning (reasoning and thinking) of statistical ideas through the use of ICT tools

  STPACK2: A critical stance towards the use and evaluation of curricula materials for teaching and learning statistical ideas with technology

  STPACK3: Conceptions of how technological tools and representations support statistical thinking and reasoning

  STPACK4: Instructional strategies for developing statistics lessons with technology

  STPACK5: Development of simulations for specific statistical content knowledge learning

  STPACK6: Design and development of complete learning scenarios based on statistical investigations using ICT tools.