PROSPECTIVE TEACHERS' STATISTICAL THINKING IN TECHNOLOGY ENHANCED INQUIRY IN THE CONTEXT OF AN INTEGRATED APPROACH

O PENSAMENTO ESTATÍSTICO DE FUTUROS DOCENTES EM PROCESSOS INVESTIGATIVOS ENRIQUECIDOS PELO USO DE TECNOLOGIA NO CONTEXTO DE UMA ABORDAGEM INTEGRADA

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ABSTRACT
The research reported in the present article aims to evaluate the teacher education learning scenarios implemented in two curricular units of the basic education course, discussing, in particular, the role of the integrated curriculum approach and of the used technologies, in the development of statistical thinking of prospective teachers. The study used a methodology within the interpretative paradigm. In order to evaluate the learning scenarios, it was used participant observation, documents' collection and a questionnaire with open-ended items whose responses were subjected to content analysis, and the frequencies of the emergent categories were determined. The results support the validation of the implemented scenarios. The students developed the reasoning about data representation and associations. The meaning of mean was a critical aspect that would deserve further research.

Key words: statistical thinking, pre-service teacher education, information and communication technologies, integrated curriculum approach, learning scenarios.

RESUMO
O estudo apresentado neste artigo tem como objetivo avaliar cenários de aprendizagem implementados em duas unidades curriculares do Curso de Licenciatura em Educação Básica, discutindo, em particular, o papel da abordagem curricular integrada e das tecnologias no desenvolvimento do pensamento estatístico dos futuros docentes. Foi usada uma metodologia no âmbito do paradigma interpretativo. Para avaliar os cenários

de aprendizagem, foi usada a observação participante, a recolha documental e um questionário com itens abertos cujas respostas foram objeto de análise de conteúdo, tendo sido determinadas as frequências das categorias emergentes. Os resultados suportam a validação dos cenários implementados. Os estudantes desenvolveram o raciocínio acerca da representação de dados e das associações. O significado de média constituiu um aspeto crítico que merece mais investigação.

Palavras-chave: pensamento estatístico, formação inicial de professores, tecnologias de informação e comunicação, abordagem curricular integrada, cenários de aprendizagem.

1. Introduction

The mathematics international curriculum guidelines (NCTM, 2007) emphasize the importance of statistical work in the classroom, reinforcing the need to develop students' ability to analyze and interpret data in order to act as critical, active and conscious citizens. This demand leads to the need of reserving special attention to this topic in teacher education programs. Teachers' mathematical knowledge has a great influence on mathematics learning of K-12 students (Fennema & Franke, 1992; Groth, 2007) and several studies show that prospective teachers have many difficulties in understanding core ideas of statistics (Garfield & Ben-Zvi, 2007). Therefore, it is very relevant to deepen the pre-service teachers' knowledge of statistics, focusing on their conceptual understanding, data exploration and use of appropriate technology. Under this scope, there is a need to focus on future teachers' statistical thinking (Wild & Pfannkuch, 1999) and, specifically, on their statistical reasoning (Garfield, 2002). This area needs to be further researched (Garfield & Ben-Zvi, 2007).

The study reported in this article is integrated in the projects *Technology Enhanced Learning @Future Teacher Education Lab* (*TEL@FTELab*) and *Eco-sensors for health: Supporting children to create eco-healthy schools (Eco-sensors4Health*). *TEL@FTELab* aims to understand how the use of technology in learning spaces offers opportunities to provide innovative ways of designing teacher education for the future. *Eco-sensors4Health* aims to use everyday technologies, such as sensors, to create healthy and sustainable environments in elementary school.

This article aims to evaluate the implementation of teacher education learning scenarios, focusing on prospective teachers' statistical thinking. The scenarios had an integrated curriculum approach, and were implemented in two curricular units of the basic education course (LEB) of Escola Superior de Educação de Lisboa (ESELx). The activities designed in the learning scenarios involve the use of mobile sensors by prospective teachers, aiming at enhancing environmental health awareness, namely in what concerns noise, as indicated by the Portuguese plan for school health (von Amann, 2015). Concerning the evaluation of the implemented learning scenarios, a discussion of the role of the (i) curriculum integration, and (ii) technologies in the development of the statistical thinking of prospective teachers will be presented.

2. Theoretical framework

Considering the multiple dimensions of the research presented in this article, this theoretical framework begins by emphasizing the role of curriculum integration in making sense of real problems, such as environmental problems. Subsequently, this study presents an analysis of the potential of everyday information and communication technologies (ICT), such as mobile sensors, in developing environmental health in teachers' education. The third part of this theoretical framework analyzes the process of developing statistical thinking in investigative learning activities, like the ones developed in this research.

2.1. Curriculum integration

Despite considering the ambiguous, polysemic and multi-faceted nature of the concept of curriculum, we assume, along with several authors (Grundy, 1987; Pacheco, 2001; Roldão, 1999; Sacristán, 2000; Schawb, 1978; Stenhouse, 1981), curriculum as a dynamic process, without a predetermined structure, and permeable to the conditions of its own implementation. This conception points to a more flexible and open curriculum, which is seen as a training project centered on students, resulting from the interaction between the planned intentionality and the experiences lived in the school context. To Roldão (1999), the curriculum is a social construction and simultaneously a historical product. Necessity and intentionality are essential characteristics of curriculum. Thus, the curriculum is born from social needs, in a given time and context, and corresponds to what the school is intentionally expected to make learn. In this perspective, curriculum is seen as a "practice in constant deliberation and negotiation" (Pacheco, 2001, p. 39), which includes the interaction between teachers and students who are considered not as mere passive objects, but as important subjects of their own learning process.

The integration of different areas of knowledge is one of the dimensions related to the curriculum that has gained importance in current days. For Morin (2001), pertinent knowledge is the one that is not compartmentalized, that is able to place the information in a context in order to allow the parts to be connected to the whole. In his view, the whole is made up of the interactions between the parts, and in turn, the whole will be retroactive on the parts. Hernández and Ventura (1998) also advocate this principle of globalization regarding the organization of knowledge. Those authors emphasize the important role of the theme or the problem, calling for the convergence of knowledge, and establishing comprehensive relations. "It is, definitely, more than an interdisciplinary or transdisciplinary attitude, a position that aims to promote the development of a relational knowledge and understanding attitude toward the complexities of human knowledge itself" (Hernández & Ventura, p. 47). In real life, we deal with complex and integrated problems and situations, but school does not reflect this reality when it applies a fragmented curriculum that applies knowledge accumulation mainly. On the contrary, an integrated curriculum demands higher order connections that stimulate a real long term understanding (Jacobs, 1989). For Beane (2000), an integrated curriculum is, in fact, a much more coherent one. Its pieces are linked in a visible and explicit way and its actions are related to a broader and stimulating purpose. Integration calls for the mobilization of all kinds of knowledge for a greater understanding of the world. According to this author, the more an event is significant, situated in context, and rooted in a cultural knowledge, the faster it is understood and learned. The "purpose of education is the making of meaning, and that can only occur if the culture of education is so designed as to make that happen" (Kysilka, 2014, p. 209). However, Kysilka (2014) remarks that there is a strong resistance to an integrated approach in several education stages.

One of the challenges of an integrated approach for teachers is the need to establish connections with other disciplinary areas, which can lead to joint work involving several teachers from different disciplines. This challenge may also entail some discomfort for teachers, since they should deal with topics that are not their specialty.

The teachers' joint work may be developed within a community of practice (COP), in the sense defined by Wenger (1998). The basic structure of a COP is composed of three elements: (1) the domain of knowledge that defines the area or the set of shared topics; (2) the community of people, concerned with the domain, creating relationships and a sense of belonging; and (3) the shared practice developed by people to deal with the domain, consisting of the body of shared knowledge and resources that enables the community to proceed efficiently (Wenger, McDermott, & Snyder, 2002). The relation, through which practice is the source of coherence of a community, has three dimensions: (1) the mutual engagement, (2) the joint enterprise, and (3) the shared repertoire (Wenger, 1998). The maintenance of a community depends on the energy produced by the community itself and not by an external mandate.

COP is a core concept of the social theory of learning (Wenger, 1998) and, in a certain way, the vision of learning as social practice resonates with a perspective of curriculum that places learners as active participants of their own learning process. Learning is seen as a situated and a social phenomenon (Lave, 1997; Matos, 2010). As a social participation, learning is the process of being an active participant in the practice of social communities and constructing identities in relation to those communities (Wenger, 1998). “Such participation shapes not only what we do, but also who we are and how we interpret what we do” (Wenger, 1998, p. 4). The social theory of learning includes components that are interrelated and characterize the social participation as a process of learning and of knowing: (a) community, (b) identity, (c) practice, and (d) meaning. So, COP entails the interconnection between these components.

2.2. Using technologies to inquire environmental health in pre-service teacher education

In an increasingly technological world, it becomes necessary for the school to follow the evolution of society. Thus, the initial teacher training should prepare prospective teachers appropriately for their practice with technology (Bru & Hinostroza, 2014; Kaufman, 2015), making them experience the resolution of tasks using technology in order to perceive how this can support the teaching-learning process (Polly, Mims, Shepherd & Inan, 2010; Tondeur, van Braak, Sang, Voogt, Fisser, & Ottenbreit-Leftwich, 2012). Despite the wider recognition of the importance of using technologies in education, several researchers show that technology is still little used by prospective teachers (Dawson, 2008; Kirschner & Selinger, 2003), referring that they continue to feel little prepared to use technology in the classroom (eg Tearle & Golder, 2008). Several studies (Brown & Warschauer, 2006; Darling-Hammond, Wei, Andree, Richardson, & Orphanos, 2009) show that initial training has a strong influence on teachers' attitudes towards ICT. Teachers who have acquired a high level of technological skills during their initial training tend to use technology in the classroom in their professional practice.

The use of digital and electronic technologies in pre-service teacher education can be guided by the idea that ICT-related objects serve as tools (not toys) within a classroom fostering the understanding of mathematical concepts and introducing new content areas (Grugeon, Lagrange, Jarvis, Alagic, Das, & Hunscheidt, 2010) in an interconnected way. In particular, a spreadsheet such as *Excel* has a general nature with multiple uses, since it may be used to store and analyze data and to represent numerical data graphically, among other functions (Tabach, Hershkowitz, Arcavi, & Dreyfus, 2008).

It is important to help pre-service teachers to achieve a better degree of integration of technology in their future teaching practices, promoting the reflection about changes in teachers' role provided by this integration. Besides the reflection, the realization of authentic learning experiences is also a core element in a pre-service teacher education that intends to prepare for technology use (Tondeur et al., 2012).

Nowadays, in Europe, and specifically in Portugal, mobile sensors are widely integrated in students' and teachers' everyday devices, such as tablets and mobile phones (Ferreira, Ponte, Silva & Azevedo, 2015), and used as extensions of human senses, for instance to record images and sounds, as well as embodied and geographical information in health and environmental activities (Silva, et al., 2009; Klasnja & Pratt, 2012). Furthermore, mobile technology with integrated sensors allows ubiquitous, formal, and informal inquiry learning activities with environmental data acquisition, processing, and presentation, using multiple representations (Peskin, 2012; Shuler, Winters & West, 2013). Nevertheless, teachers' education in such mobile learning strategies is not satisfactory yet (Shuler, Winters & West, 2013).

Following the European and the Portuguese digital agenda, in this research, the use of mobile and ubiquitous technologies, namely mobile sensors, aims at contributing to the development of the digital literacy of future teachers and of their future students. The relevance of this contribution has been widely recognized (European Comission, 2017). Sensors have been recognized as short-term promising technologies to elementary and higher education (Johnson, Adams, & Cummins, 2012a; Johnson, Adams, & Cummins, 2012b).

2.3. Statistical thinking

It is recommended that statistical work in the classroom should be carried out by conducting empirical inquiries on current themes and of the interest of students (NCTM, 2007). Wild and Pfannkuch (1999) consider four dimensions in empirical inquiry: the investigative cycle, types of thinking, the interrogative cycle, and dispositions.

The investigative cycle involves different phases: question posing (*problem*), sampling design (*plan*), data collection and organization (*data*), data representation (*analysis*), and interpretation and communication of results (*conclusions*) (Ponte & Fonseca, 2001; Watson, 2006; Wild & Pfannkuch, 1999). "The conclusions from the investigations feed into an expanded context-knowledge base which can then inform any actions" (Wild & Pfannkuch, 1999, p. 225), conducting to a new investigative cycle.

In the next dimension, Wild and Pfannkuch (1999) analyze the types of thinking required for statistical work. According to the authors, in carrying out this type of work, it is necessary to take into account types of thinking specific to statistics and some general types of thinking. The more general types of strategic thinking resemble the problem-solving model proposed by Pólya (Shaugnessy, 2006). Next, we present the essential characteristics of the types of thinking specific to statistics:

Recognition of need for data - This aspect is of great importance in the development of statistical thinking. This strand means that the investigation begins with a question or a problem that is intended to solve, which makes the need for data (Burgess, 2007).

Transnumeration - It is the ability to order data appropriately, create tables or graphs from the data and find statistical measures that best represent the data set. It involves changing the data representations for the data to make more sense (Wild & Pfannkuch, 1999).

Consideration of variation - The consideration of variation is a core element of statistical thinking, being omnipresent in all statistical processes. There is a need of designing data production with variation in mind and of quantifying and explaining the variation (Watson, 2006). Variation affects decision-making based on data, because without an understanding of variation, people tend to express generalizations as being certainties rather than possibilities (Burgess, 2007).

Reasoning with statistical models - This aspect is necessary to be able to make sense of the data, which includes, for example, reasoning about graphs, tables and measures (Burgess, 2007).

Integrating the statistical and contextual - Context is a very significant component of statistical thinking (Watson, 2006) which is a synthesis of statistical knowledge, context knowledge and the information in data. There is a "continual shuttling backwards and forwards between the thinking in the context sphere and the statistical sphere" (Wild & Pfannkuch, 1999, p. 228) throughout the investigative cycle. One has to make connections between the context-knowledge and the results of statistical analysis to arrive at meaning. This is why major out school investigations are driven through bringing together people of differing expertise. Ben-Zvi and Makar (2016) refer to the context as a key challenge to face insofar it "may mislead the students, causing them to rely on their experiences and often faulty intuitions to produce an answer, rather than select an appropriate statistical procedure" (p. 2).

To Wild and Pfannkuch (1999), the interrogative cycle is related to working with data through activities such as generating data, seeking information, interpreting the results of the inquiry, criticizing the incoming information and ideas, and judging what to discard or to believe.

According to Shaugnessy (2006), the dispositions referred by Wild and Pfannkuch (1999) have much in common with problem solving, because, to try to solve a problem, one has to be curious, to be aware, to have imagination, to be skeptical, to be open to alternative interpretations and to seek a deeper meaning, as in the "look back" phase of Pólya's model.

Focusing now on the type of reasoning with statistical models, we can pay attention to the concept of statistical reasoning that is defined by Garfield (2002) as how people reason with statistical ideas and give meaning to statistical information, involving interpretation-making based on graphical representations, data sets, or statistical summaries. Having a statistical reasoning "means understanding and being able to explain statistical processes and interpret statistical results completely. (...) Thus, the development of statistical reasoning enables the student to understand, interpret and explain a statistical process based on real data" (Lopes & Fernandes, 2014, pp. 72-73). There are several types of statistical reasoning: (i) reasoning about data; (ii) reasoning about data representation; (iii) reasoning about statistical measures; (iv) reasoning about uncertainty; (v) reasoning about samples; and (vi) reasoning about associations (Garfield & Gal, 1999).

When reasoning about data, the students recognize and categorize the data and they know how to use a specific representation or measure for a given type of variable. When reasoning about data representation, the students understand how to interpret graphs and what graph is appropriate to represent a set of data. They also recognize the general characteristics of a distribution by its graph. When reasoning about statistical measures, the students understand the meaning of the measures and what the most appropriate measures to use in a set of data. When reasoning about uncertainty, the students understand and use randomness and probability to make judgments about events. When reasoning about samples, the students understand their relation to the population and they are able to take precautions when a population is examined based on small samples. Finally, when reasoning about associations, the students are able to interpret the relations between variables and they understand that a strong correlation between two variables does not mean that one is the cause of the other.

The implementation of a learning environment conducive to the development of students' statistical reasoning requires, according to Garffield and Ben-Zvi (2009), the adoption of six principles: (1) to focus learning on the development of central statistical ideas rather than procedures; (2) to use data sets that are real and motivating, leading students in making and testing conjectures; (3) to use classroom activities to support the development of students' reasoning; (4) to integrate the use of appropriate technological tools that enable students to test their conjectures, explore and analyze data; (5) to promote a discourse in the classroom that includes statistical arguments and discussions focused on meaningful statistical ideas; and (6) to use a formative assessment to perceive what students know and to monitor the development of their statistical learning as well as evaluate the planning and progress made. Although the authors refer to these principles to elementary, middle or high school, we consider that they are equally valid in the context of pre-service teacher education, not only to promote their statistical reasoning, but also due to the possible isomorphism of practices that they may transfer to their future teaching practices. It has also been recognized the important role of technologies in increasing the comprehension of statistical concepts (Konold & Lehrer, 2008).

3. Methodology

The present study is focused on the evaluation of learning scenarios, aiming at the analysis and signification of data related with environmental health variables and acquired using sensors. The evaluation takes into account the prospective teachers' statistical thinking. The scenarios were realized in 2016-17, in two curricular units of LEB in ESELx: Data Analysis (DA) and ICT in Mathematics and Natural Sciences (ICTMNS). The authors of this article were the teachers of those curricular units. In DA, the learning scenario involving the use of sound sensors was implemented. In ICTMNS, the learning scenario involving the use of a heart rate sensor was implemented.

A qualitative methodology, within the interpretative paradigm, was used. Data collection included: (i) participant observation of classes; (ii) documents' collection (individual and team works produced by the students, namely reports on their inquiry process, presented in portfolios); and (iii) questionnaires. The students evaluated each learning scenario through a specific questionnaire.

The questionnaires presented open-ended items whose responses were subjected to content analysis. The option for open-ended items ensures the collection of a wider set of information, sometimes richer and more detailed than closed ones. Eventually, open questions could facilitate the emergence of responses with data that were not originally planned (Hill & Hill, 2008).

For the content analysis, we grouped similar answers in the same category, as advocated by Bardin (2009). Therefore, we defined posterior categories for a better understanding of the students' opinions about learning scenarios. At the end, the respective frequencies were determined. Concerning prospective teachers' statistical thinking, we used analytic categories from the theoretical framework of Wild and Pfannkuch (1999) and Garfield and Gal (1999).

The design of the scenarios followed some principles: (i) curriculum integration through the mobilization of mathematics, natural sciences and technologies in authentic and situated activities; (ii) inquiry of real and proximal problems related with the environmental health with sensors and other technologies, following an investigative cycle; (iii) promotion of the autonomy of pre-service teachers regarding the investigation phases; (iv) promotion of a productive discourse focused on meaningful statistical ideas; (v) formative assessment with monitoring of pre-service teachers' learning; and (vi) promotion of pre-service teachers' technological pedagogical content knowledge, in accordance with *Technological Pedagogical Content Knowledge* (TPACK) model (Annex 3). This model, proposed by Mishra and Koehler (2006), emphasizes the complex interrelation between subject matter, pedagogy and technology domains. Due to space limit, it will not be analyzed in the present article.

The mentioned design contemplated the future classroom maturity model (ITEC Project, 2014), positioning the considered dimensions (Annex 4) in different levels, according to the model reference, both with respect to the moment before the implementation of the scenario, as well as to the desired level that the scenario would intend to achieve. This model also framed the scenarios' evaluation.

3.1. Data Analysis Curricular Unit

A two-lesson learning scenario in DA was implemented, functioning at the 1st semester, in three classes of the 2nd year of LEB, in a total of 92 students. The scenario aimed at the collection, organization, treatment and analysis of sound level data in different ESELx locations, in the context of the relationship between sound level and environmental health in school.

The data were collected by the students with the sound sensors of their smartphones, through the application SPARKvue, and then exported by email to be treated in *Excel*. The pre-service teachers constructed graphical representations in *Excel* and interpreted them in the light of a scientific text alluding to noise. They also determined statistical measures.

To evaluate the scenario, a questionnaire was handed to each student of the three classes. This study focuses on questions 1, 4 and 5, presented in Annex 1.

3.2. ICT in Mathematics and Natural Sciences Curricular Unit

ICTMNS is an optional curricular unit, functioning at the 2nd semester. The class was composed of eight students who attended a post work class of the 2nd year of LEB. The learning scenario here reported had a duration of two lessons in a total of four hours. It aimed at the collection, organization, treatment and analysis of heart rate data in different ESELx locations.

The students used a heart rate sensor in conjunction with the *Endomondo* app to monitor heart rate variability in the school environment and during the dramatization of a 'Parliament' debate on the Almaraz Nuclear Power Plant. The graphical representations created by the software were exported to *Google Earth* and interpreted by the students who also interpreted statistical measures.

The students should develop portfolios to contemplate the report of one of the activities developed in the classes. Two pairs of students chose heart rate activity for their reports, and the study analysis included their work, here designated as Ra and Rb. For ethical reasons, we changed real pre-service teachers’ names to fictitious ones.

To evaluate the scenario, a questionnaire (Annex 2) was applied to each pair of students, whose responses were coded as Qa, Qb, Qc, and Qd.

4. Results

4.1. Using sound sensors (DA)

4.1.1. Collecting and analyzing data

In each of the classes, the students, organized in groups, collected the sound level data for five seconds at different ESELx locations, each group being responsible for a location. The selected locations were: (i) bar; (ii) refectory; (iii) classroom; (iv) outside garden; (v) library; (vi) study zone I; (vii) study zone II; and viii) Noble Hall. Before the data collection, they made predictions about the sound level in these places, framed by a scientific text that presented a scale of sound levels. Afterwards, these predictions were confronted against the collected data.

In the several places, each group recorded the location and the moment of data collection through photographs (Figures 1 and 2).

Figure 1: Collecting sound level data in the library

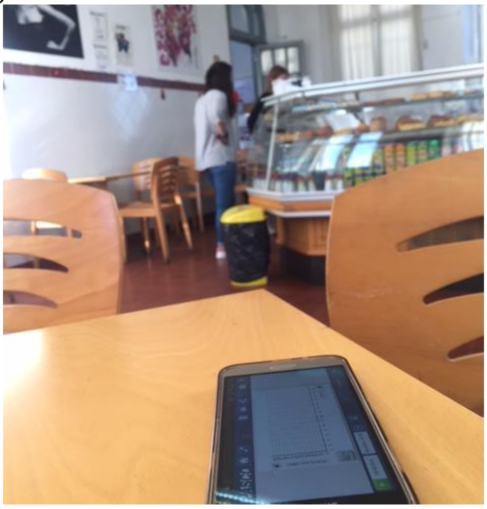

Figure 2: Collecting sound level data in the bar

After the data collection, the students returned to the classroom and opened the *Excel* spreadsheet with the collected data, and performed a statistical analysis, which was sent to the teacher's e-mail (Figure 3).

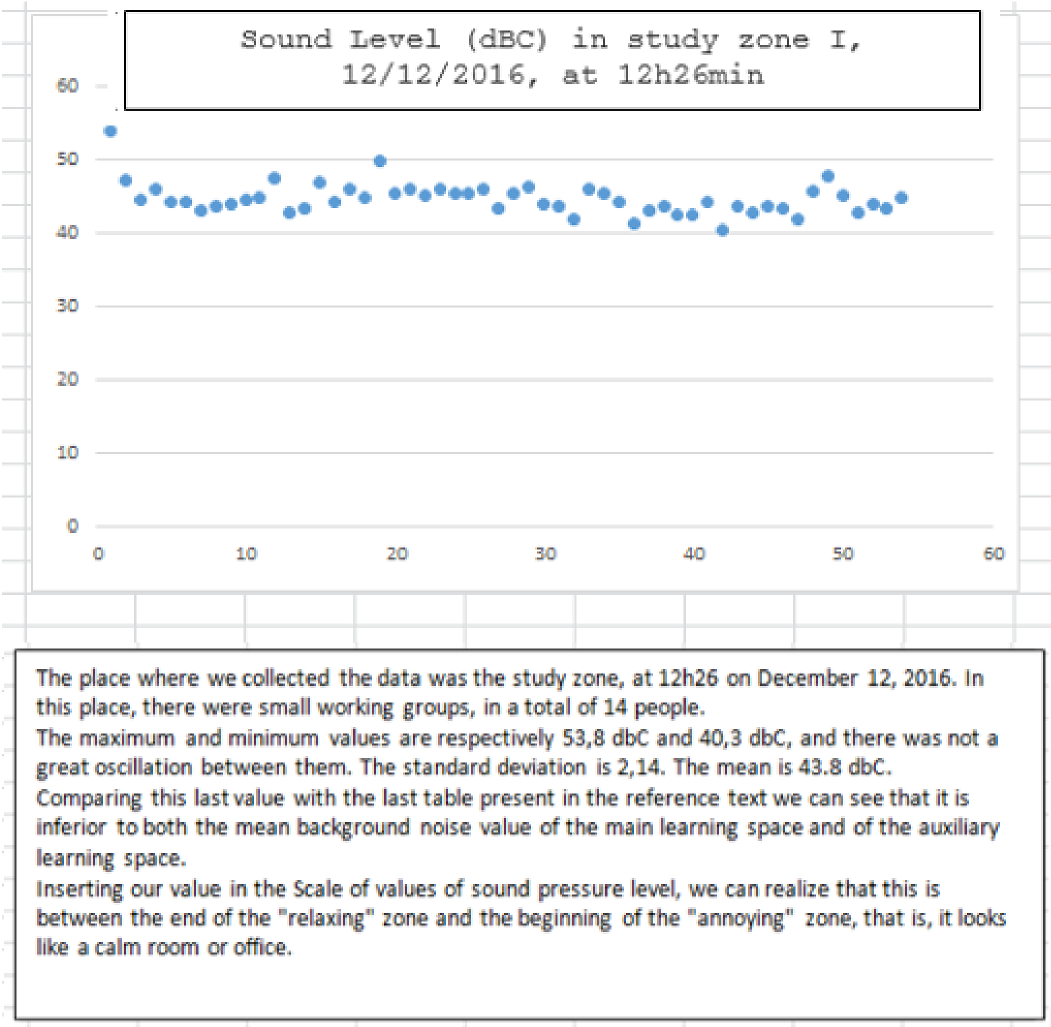

Figure 3: Report of statistical analysis sent by e-mail

In this analysis, the students, autonomously, determined, among others, the minimum and maximum values, the mode, the mean and the standard deviation of the data collected. After this work, using *Excel*, they constructed graphs on the same spreadsheet, based on the sound level records of each group, and subsequently analyzed them. At this moment of data treatment and analysis, the students were able to put into practice some statistical content previously worked in DA.

Since sound level data are highly dependent on what was happening in each place, at the collection moment, as can be seen in Table 1, the values obtained by each group of students varied from place to place and from class to class.

Table 1: Extreme values of sound level in the different places

Class	C		D		E		Mean	
Collecting Hour	12h15/12h30		12h15/12h30		15h00/15h30			
Place	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**
Bar	45.1	60.6	64.9	80.6	58.2	68.7	**56.1**	**70.0**
Refectory	40.4	58.0	69.2	79.4	61.7	69.3	**57.1**	**68.9**
Classroom	52.3	67.2	54.6	65.6	55.0	70.4	**54.0**	**67.7**
Outside garden	52.4	67.4	59.1	63.6	42.8	49.0	**51.4**	**60.0**
Library	32.5	51.6	29.5	31.6			**31.0**	**41.6**
Study zone I	45.9	67.6	40.3	53.8	29.9	41.5	**38.7**	**54.3**
Study zone II			46.2	62.7	25.9	49.5	**36.1**	**56.1**
Noble Hall					27.2	58.8	**27.2**	**58.8**

Throughout this work, the students were able to experience some of the dimensions of the statistical work presented by Wild and Pfannkuch (1999). With regard to the investigative cycle, the students could try to understand a problem of their school reality, defining a plan of work in a large group and collecting and analyzing the data in small groups. On the other hand, regarding the second dimension presented by the authors, types of thinking, with concern to statistical specificities, students perceived the need for data collection, the importance of context in statistical work, as well as the importance of transnumeration by passing the data from a data record table to a point plot followed by the determination of statistical measures. Respecting the interrogative cycle, the students did not have to research information about the subject since it was the teacher who proposed the task and provided the supporting text. So, they focused on the interpretation and analysis of the collected data. Finally, with regard to the fourth dimension, it was possible to perceive that the students showed themselves curious and open to the type and theme of work, involving themselves along the two lessons that were destined to its accomplishment.

4.1.2. Evaluating the learning scenario through the questionnaire

The analysis of pre-service teachers' answers (92) to the questionnaires made it possible to verify that the majority (82%) considered the task to be pertinent, and the justifications referred mainly to the subject matter under study (sound, with 36% of the responses) and the use or consolidation of statistical concepts previously worked in DA (20%).

Concerning this learning scenario, the students said they were favorable to the use of ICT, 90% of them considered pertinent the use of the smartphone to carry out the proposal, and 95% considered relevant to use *Excel*. The main justifications for the importance of using *Excel* mentioned its usefulness for statistical work (38%) and the fact of having allowed them to learn or remember its mode of use (33%). Despite these high values, it is noteworthy that some future teachers considered the use of smartphone (10%) and of *Excel* (5%) as strategies that are not relevant to learning.

4.2. Using a heart rate sensor (ICTMNS)

4.2.1. Collecting and analyzing data

Two students (one at a time) collected their heart rate data, making different routes outside the school, accompanied by colleagues who recorded the locations and events so that they could then interpret the variation observed in the graph. By analyzing the heart rate sensor data exported by the *Endomondo* app and presented in *Google Earth* (Figure 4), the students found that the heart rate, besides varying from person to person (the first student, Ilda, had a higher mean rhythm), had also varied according to the physical effort developed along the course (ramps, irregularities and different elevations of the terrain) and in moments of increased stress when walking over a wall with closed eyes, or walking on a narrow bar trying to keep the balance with closed eyes, for example.

Figure 4: Altitude and heart rate graphs of two students with *Google Earth* route

Concerning the statistical ideas, the students verified that "the data collected are represented in (...) line graphs" (Ra) and that the line graph does not represent the absolute or relative frequencies, as other graphs (pictograph, pie or bar graphs), but represents the data itself relating it to the time variable: "this type of graph is used to represent how the variable evolves, being the variable in study a continuous quantitative one, that varies according to the time, in this case, the number of heart beats per minute" (Rb). In the classroom, the students recognized that they had no need to categorize the data nor to organize it. They also recognized that they did not work with a sample, in the sense of a subset representative of a population, in so far as they analyzed the data regarding only two observational units (the two students). However, they did not refer these aspects in their reports: there is no reference to the absence of data categorization or discussion about the notion of sample.

The students explained the extreme values of heart rate to each student that has used the sensor, relating them with the involved factors. In Rb, it can be read: "Ilda (observational unit) was running for a few minutes, whereby her heart rate marked 149 bpm with this value being the maximum recorded. The minimum value was 127 bpm and the mean was 124 bpm". As we see, these students made a mistake in the record of minimum value and they did not question the impossibility of having a mean lower than the minimum.

The pre-service teachers also reflected about the pertinence of having the two graphs in the same graphical area as displayed in *Google Earth*: the altitude graph (upper row) and heart rate graph (bottom row). Both graphs show the data variation over time facilitating the establishment of relationships between the studied variable, heart rate, and other variables that may influence the heart rate variation, as is the case of altitude (associated to the effort caused by climbing). The *Google Earth* display was important, allowing to relate the variation observed in the graphs with the made routes, thus facilitating the relationship with the recorded events. This aspect, in particular, was mentioned in all questionnaire responses. Relative to the question 3 of the questionnaire, the following responses were obtained:

- "It was possible to verify that there are oscillations in the heart rate with variables such as: Time; Distance; Speed; Altitude. (...) It gives the possibility of relating several variables simultaneously and reading them" (Qa);
- "The advantage of being able to observe the data of different variables in the same graphical area, in this way it allows a better interpretation of the obtained results" (Qb);
- "On the other hand, *Google Earth* makes it possible to observe the bpm taking into account the route and location of the person who is using the sensor. (...) The combination of these two instruments makes possible a more complete analysis from which questions may arise, for example: what factors contribute to the variation of the heart rate in daily life?" (Qc);
- "In this way we can see the interconnection of all variables and the joint evolution of them" (Qd).

During the simulation of a 'Parliament' debate on the Almaraz Nuclear Power Plant, another student used the heart rate sensor and the respective graph can be seen in Figure 5.

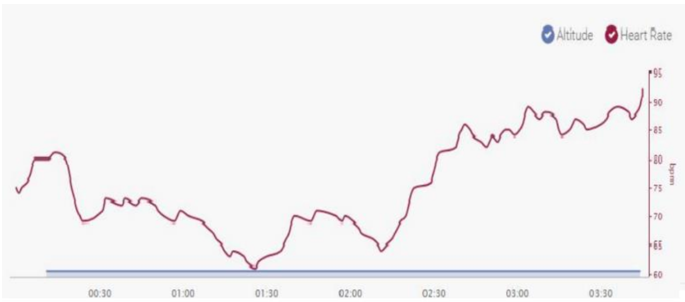

Figure 5: Heart rate graph of a student during the debate

Analyzing this representation, the students interpreted that their colleague's heart rate began to rise ("Initially the heart rate (...) began to rise until 81 bpm, this situation was due to the beginning of the debate (...), [she] should be more anxious.", Ra), staying, after, relatively low while the other students discussed ("led to Sara's heart rate dropping to 61 bpm, of all measured values this was the lowest." Ra), until she was interpellated by the teacher to enter into the discussion about the environmental impact of the Almaraz nuclear power plant, and so her heart rate went up in this final moment ("From this moment her heart rate was accelerating, reaching 92 bpm, the highest measured value.", Ra). So, students concluded that "not just with physical exercises, but the emotions also influence the heart rate" (Rb).

At the end of the activity, the students recognized the relationship between heart rate variations and environmental (dis)comfort: "It was possible to observe that our heart rate is constantly changing and that change is directly associated with our lifestyle and the environment that surrounds us, directly affecting our health and well-being." (Qc).
They compared the mean values ("Her [Ilda's] mean heart rate per minute was 124 bpm"; Anabela - "106 bpm", Sara - "76 bpm", Ra), concluding that

> in these three observational units it was possible to verify that the heart rate of each one is different. The one of Ilda is more accelerated, whereas the one of Anabela and of Sara is quieter, which does not compromise that each heart rate varies in the same way after a variable. For both the heart rate of Ilda and that of Anabela, who have completely different heart rates, behaved in the same way after more effort, that is, their rhythms accelerated. As in less effort, their rhythms slow down. (Ra)

So, the students revealed the awareness of analyzing the data related with three observational units, interpreting heart rate variation in function of other variables represented in the graphical area: "In short, it is possible to affirm that there are several causes that alter the heart rate. It was possible to verify that with Ilda and Anabela, their beats per minute changed, according to speed and altitude. With Sara variations, due to the environment and her emotions, were verified." (Ra).

Regarding the types of statistical thinking, the most evident in this activity are the consideration of heart rate variation and integration of the statistical and contextual knowledge. The latter is related with the need of synthesizing the contextual knowledge (the events recorded during their routes and the debate) with statistical knowledge and scientific knowledge from natural sciences in order to signify the means and the line graphs obtained. The students showed also the ability to understand how to read and interpret graphs (reasoning about data representation) and to judge and interpret the relations between variables in graphs (reasoning about associations). However, there is a lack of comprehension of the meaning of mean insofar the students did not use a critical thinking in questioning the recorded values (Rb).

4.2.2. Evaluating the learning scenario through the questionnaire

All pairs of students (4 pairs), in the questionnaire responses, referred that it was the first time they used heart rate sensors. They have already used *Google Earth* to search for a particular location but it was the first time they used it to explore the graphs.

All pairs of students considered the activities developed pertinent to their learning referring the significance of the relationship between heart rate variation and multiple factors.
The totality of the answers considered useful to use the heart rate sensor for future teaching, justifying with (i) the connection among various curricular areas, and (ii) the importance of the theme and the experimentation.

> The implementation of the activities (...) was an added value in the acquisition of knowledge by students, as it made possible the understanding of magnitudes that previously (...) were unknown.
> For a teacher's professional future, it is important to be aware of the school's possibilities, at the level of tools (...), so that, in this way, it is possible to structure and carry out activities similar to those carried out in the lessons of this curricular unit.
> It is concluded that information and communication technologies play a very important role in the teaching and learning process. Teachers, as guides of the teaching process, are fundamental for students to familiarize themselves with these new tools. (Ra)

In this transcript, the students emphasize the role of ICT in promoting learning, and assume the isomorphism of practices transferring what they experienced at ICTMNS to their future teacher practices.

4.3. Evaluating the learning scenarios using future classroom maturity model

In the implemented learning scenarios, some evolution of the maturity levels was verified, namely in the following dimensions:

- *learners' role* - from 2 to 3. The students enhanced their digital competence by using technologies they did not know before, in the investigation of environmental issues, showing self-understanding and confidence in their progress and learning that was rebalanced between whole class and group activities;
- *teacher's role* - from 3 to 4. The activities were developed autonomously by the students in places outside the classroom, and designed with a clear focus on learning and on learner engagement and empowerment;
- *school capacity to support innovation in the classroom* - from 3 to 4. There was an investment in the acquisition of new technologies such as sensors, which was accompanied by technical training, as well as encouragement in collaboration among teachers in the design of learning activities using multiple resources (this collaboration led to the emergence of a COP in ESELx); and

- *tools and resources* - from 3 to 4, in the case of ICTMNS. New uses or new technologies were successfully adopted in all lessons (even the ones not reported in the present article), both inside and outside the classroom, to support learning.

Other dimensions remained at the current level:

- *learning objectives and assessment* - 2. The short duration of the learning scenarios did not allow evolving from learning objectives defined by the teachers to a greater involvement of the students in defining and personalizing them; and
- *tools and resources* - 3, in the case of DA. The use of new technology in the collection and analysis of data occupied a reduced percentage of the curricular unit lessons.

The joint enterprise of designing the learning scenarios brought out a COP (Wenger, 1998) that included the mathematics and natural sciences teachers engaged in the two projects, also including the students that were participants in the activities designed, which had an integrated curriculum orientation. All COP members developed a shared practice, repertoire, and concern to deal with the activities. So, our practice on designing the learning scenarios was the source of coherence of this emergent COP leading to (i) the joint enterprise of designing and sharing the implementation of the learning scenarios, with class co-teaching, and (ii) the mutual engagement between teachers of disciplinary areas that usually are taught separately, namely in higher education. The scenarios' implementation extended COP to students through the development of a shared repertoire (Wenger, 1998), consisting of shared knowledge related with environmental health involving natural sciences topics, and with data analysis involving statistical concepts and representations. It is to say that all the members shared a concern with the proposed activities developed, in part, outside the classroom. This COP did not entail homogeneity. The mutual engagement was characterized by diversity and it was inherently partial since the several members assumed different roles depending on their competence.

5. Conclusion

The activities designed in the learning scenarios aimed to prepare teaching practices that lead to the empowerment in the use of sensors to intervene in the environmental health of schools, while developing statistical thinking. The evaluation validated the scenarios, considering the future classroom maturity levels and the questionnaires responses. We remark the efficiency of the strategy used, attending the achievement, in two lessons, of the objectives of statistics and environmental health. It is worth highlighting the pertinence of the implemented learning scenario for future teaching practices identified by ICTMNS students. That relevance was mainly justified by the importance of experimentation and by the curricular integration. Those students reflected about the role of ICT relating it with a teacher´s role assumed as a guide of learning processes (Grugeon et al., 2010).

The learning goals of the scenarios are related to ICT, mathematics, specifically statistics education, and also to natural sciences, in an integrated way (Beane, 2000).

The educational project of ESELx emphasizes the curricular integration approach in pre-school and elementary school and our prospective teachers are taught within this orientation. However, most of the curricular units of the several courses are organized in an atomic way, due, mainly, to the need for specialization in each of the disciplinary areas. As observed by Kysilka (2014), there is a strong resistance to an integrated approach in several education stages. However, there is a lack of research related to the adoption of this approach in the university stage. An integrated approach is a very demanding one, not only for teachers but also for students, even when aware of its several benefits to learning. The joint design of the teacher education learning scenarios led us (the authors of this article, mathematics and natural sciences teachers) to a collaborative work that spawned a COP (Wenger, 1998). This emergence resulted from the need to work an integrated approach in pre-service teacher education in which we had a common goal: to develop the pre-service teachers' knowledge about the uses of everyday digital technologies in didactic activities of acquisition and analysis of environmental health data.

Regarding the development of prospective teachers' statistical thinking, the learning scenarios design was in line with the principles defended by Garffield and Ben-Zvi (2009) such as the use of (i) real and motivating data sets, and (ii) technological tools that allow students to explore and analyze data. It is worth noting that the students revealed specifically some types of statistical thinking (Wild & Pfannkuch, 1999), such as: (i) the consideration of variation, noticing and acknowledging it, as well explaining and dealing with it in the scope of the phenomenon comprehension, the heart rate variation; and (ii) integrating the statistical and contextual knowledge, through the synthesis of the both types of knowledge with the data information. Students' engagement in the real experiences developed and their curiosity and awareness in observing and interpreting the data representations were possible contributions for those results, since they are relevant dispositions, remarked by Wild and Pfannkuch (1999), for statistical thinking.

In what concerns the types of statistical reasoning, the students showed evidences of developing, above all, the reasoning about (i) data representation (they were able to understand how to read and interpret graphs), and (ii) associations (they were able to judge and interpret the relations between variables in graphs). As a critical aspect that would deserve further research, is the meaning of mean which seems to be not fully understood by the totality of ICTMNS students.

The results of this study show the diversity of future teachers' opinions regarding the use of ICT. Although most of the students considered the scenarios to be relevant, using sensors, the smartphone and *Excel*, some indicated the use of the smartphone as a distractor and the use of *Excel* as something irrelevant for being a software already known to students. It is therefore important to continue to research, in particular through focus groups and interviews to the study's participants, about the use of ICT in teacher education, aiming at innovative practices of future teachers.

The integrated approach involving the use of ICT enabled the learner’s empowerment and engagement, accompanied by the teacher’s role as a team leader with coordination and planning responsibilities. That engagement fostered prospective teachers' statistical thinking, due mainly to the realization of authentic learning experiences that make sense of environmental problems.

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Annex 1. Selected items of the questionnaire delivered to students in Data Analysis Curricular Unit

1. How do you evaluate the proposed task in terms of pertinence?

4. How do you evaluate the pertinence of using your smartphone to perform this task?

5. How do you evaluate the pertinence of having used the spreadsheet for this task?

Annex 2. The questionnaire delivered to students in ICT in Mathematics and Natural Sciences Curricular Unit

1. Have you ever used a heart rate sensor?

2. Have you ever used Google Earth?

3. How useful is the joint use of the heart rate sensor and Google Earth?

   3.1. With regard to the meaning of the information acquired and exploitable, namely the various magnitudes and variables presented?

   3.2. With regard to the multiplicity of graphical representations and the possibility of interaction with them?

4. What learning did enable the activity with the heart rate sensor?

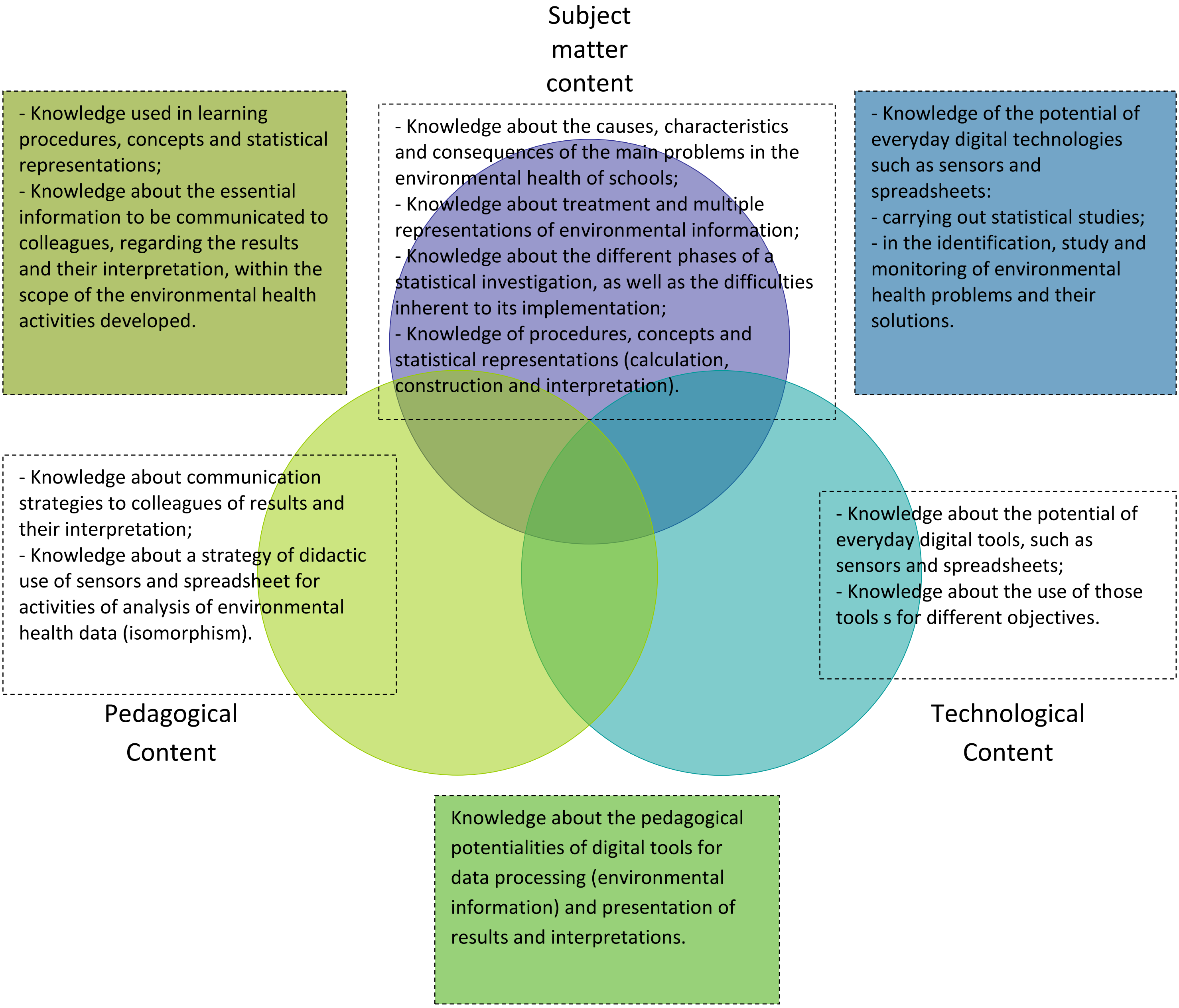
   4.1. With regard to the knowledge of the heart rate magnitude, its variation with various factors and its relation to the well-being and health of each person?

   4.2. With regard to the school outer spaces?

   4.3. With regard to the environment in the classroom?

5. Do you consider useful to use the heart rate sensor for future teaching? Explain how.

Annex 3. TPACK model applied to the design of the learning scenarios



TPACK model

Knowledge about the uses of everyday digital technologies in didactic activities of environmental health data analysis.

Annex 4. Considered dimensions of future classroom maturity model

Dimensions	Maturity levels	
	Actual	**Intended**
Learners' role	2 - Enrich There is a good relationship between learning objectives (agreed between several teachers), learning activities and assessment (using technology) which encourages different types of active learning, i.e. through inquiry, discussion, collaboration, practice and production, as well as acquisition. The learner has the opportunity to use the feedback and assessment evidence (stored digitally) to improve their performance.	3 - Enhance Learners collaborate, supported by technology, to gain information and knowledge, and choose and use appropriate digital technology, based on self-understanding of their learning and progress. Learners can demonstrate that they are digitally confident and competent as creators of products, knowledge and new ideas. Learners are involved in more independent learning supported by technology and engaged in online collaborative problem-solving or research, activities, with the learning rebalanced (e.g. between whole class and group activities).
Teacher's role	3 - Enhance The teacher is comfortable with re-organising classroom layout, introducing new tools and resources into the classroom including those suggested by students and colleagues. The teacher helps students incorporate multimedia production, web production and publishing technologies into their projects in ways that support their ongoing knowledge production and communication with other audiences.	4 - Extend Teaching is less time and place dependent, bridging the gap between formal and informal learning, and there is a shift in role of the teacher from subject expert to learning designer (learner/researcher). The teacher is digitally competent and connected to others, using a diversity of approaches organised around the learner and designing activities that engage and empower the learner and build their confidence (e.g. the learner as a teacher, expert or team leader with planning and coordination responsibilities).
Learning objectives and assessment	2 - Enrich There is a good relationship between learning objectives (agreed between several teachers), learning activities and assessment (using technology) which encourages different types of active learning, i.e. through inquiry, discussion, collaboration, practice and production, as well as acquisition. The learner has the opportunity to use the feedback and assessment evidence (stored digitally) to improve their performance.	3 - Enhance The learner is involved in defining clear learning objectives which are more personalised and progress through a task is tracked to assess process skills alongside knowledge and understanding. This provides quality feedback from a range of assessment approaches (including self- and peer-assessment, formal and informal), to improve their performance and redefine learning objectives. Objectives include higher order thinking and key subject specific process skills such as enquiry skills in science or presentational skills in languages.
School capacity to support innovation in the classroom	3 - Enhance The school encourages teachers to experiment and take risks with new approaches to learning and teaching, particularly approaches that support greater personalisation, learner responsibility for their own learning, and engagement with parents, leading to improved learning outcomes. School strategy includes digital learning, with teachers receiving appropriate training to achieve this, and technical and pedagogical support is provided	4 - Extend Sufficient investment to meet demand is made in technical support, infrastructure and professional development (including technology for learners with special needs). The school encourages and supports collaboration between teachers, within schools and with other schools to share good practice. Participation in online CPD and communities of practice that support collaborative design of learning activities and resources is common.
Tools and resources	3 - Enhance Technology is in use effectively in 25-50% of lessons. Learning is personalised and supported by intelligent content and widely available networked technology providing timely progress/performance data, guiding decision making. Technologies are used for collaboration, communication, to solve real-world problems and creativity (authoring tools, creating games, modelling and making).	4 - Extend Technology is in use effectively in 50-75% of lessons. Teachers and students identify and use new technologies, tools, resources and services, and/or identify new uses for established technologies to use in teaching. Learners are supported by distributed, connected technology (sometimes subject specialist) in ways which are not commonplace in schools, and technology is used in and out of school supporting learning at non-traditional times and locations. Sharing of tools and resources among teachers and students is commonplace.