DEVELOPING "RECOGNITION OF NEED FOR DATA" IN SECONDARY SCHOOL TEACHERS

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ABSTRACT

This paper describes the evolution of "recognition of need for data" and "strategical thinking", two types of thinking identified by Wild and Pfannkuch in their Framework for Statistical Thinking in Empirical Enquiry, as well as its relevance for math teacher professional development. The research was carried out with ten in-service secondary-school math teachers during an educational experience (at Bogotá, Colombia), who, in the beginning, showed high performance in procedural knowledge of data analysis. The experience was founded on project-based learning that participants proposed and conducted via a survey concerning implications of a Bill, relevant for their job context. These teachers made mistakes and showed difficulties during the two first stages of the investigative cycle, problem formulation, and research planning, due possibly to their inexperience in designing an empirical inquiry. Teacher educator's guidance, to turn mistakes into learning opportunities and teachers' active participation, promoted the development of statistical thinking, especially linked to the types aforementioned.

Keywords: *Statistics education research; Project-based learning; Teacher development; Statistical thinking.*

1. INTRODUCTION

For some decades, educational politics of different countries (e.g., Colombia–Ministerio de Educación Nacional [MEN], 1998; United States - Franklin et al, 2007) and many educational statistics researchers have promoted contextualized teaching of statistics, as well as using different options of active learning in the classroom, because of the advantages for developing statistical thinking (e.g., United States–Chance, 2002; New Zealand–Burgess, 2007; United Kingdom–Marriot et al., 2009). In 1999, Wild and Pfannkuch identified *recognition of need for data* as a fundamental type of statistical thinking. However, in a graduate course with in-service math teachers, carried out at Bogotá (Colombia), this type of thinking was unknown to them. The participants argued that, from their perception, "data always are available nowadays", based on the availability of open databases and many indexes published by many sources on different media platforms. However, sometimes these open data do not respond to local questions. For example, nowadays there are a lot of data about contagion, disease and death by COVID-19 in different countries, even so each country (indeed each city) must collect its own data for the development of epidemiological models and suitable decision-making.

This classroom research aimed to develop recognition of need for data in a group of math teachers, participating in a master's degree program. The research was guided by this investigative question: What steps, on Problem and Plan stages of a statistical inquiry, could foster development of recognition of need for data in math teachers with experience with a reduced project? First, it was sought to face teachers to conduct a real statistical inquiry entirely. Starting from asking an authentic question for a local social problem, and without data available on the web, to go through all stages of an empirical inquiry, especially its planning.

During the experience, there was evidence of a lack of strategical thinking for statistical enquiry, which led to the posing of other investigative questions: How does project-based learning (PBL) foster the development of strategic thinking and recognition of need for data? What are the advantages, disadvantages, and limitations of PBL for this development? The analysis seeks to show the incidence of the dispositional component in the development of these two types of thinking.

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2. LITERATURE REVIEW

Various researchers had been interested in the benefit of the learning process of empirical inquiries (with quantitative analyses), after Stuart (1995) explained and illustrated solving statistical problems as an option for teaching statistics. He contrasted this strategy with teaching from a mathematically oriented approach. Stuart precisely listed the pedagogical advantages of introducing problem formulation and data collection as part of the teaching statistics cycle. His conclusion remains valid: "The problems of statistical practice are different from mathematical statistics. Statistics ideas (and not their mathematical abstractions) should be the focus of our teaching" (p. 54).

Informing this study is the work of Green and colleagues (2018), who summarized approaches of different authors about developing statistical thinking and reasoning, also teachers as students, and linkage with problem-solving implementation in classroom practices. In this report only the most relevant papers for this study are cited. First, presented are the two types of thinking and suggestions for their development considered in this research. After that, summarized are conceptual and observational analyses with in-service or prospective math teachers about developing knowledge for teaching statistics.

2.1. STATISTICAL THINKING IN EMPIRICAL ENQUIRY

Wild and Pfannkuch (1999) proposed a model that complements the mathematical models mainly related to data analysis concerned with the thinking processes involved in solving statistical problems. The authors based their model on the background and in-depth interview analysis of 16 statistics students and six statisticians who worked on projects. Their framework is composed of four dimensions, not mutually exclusive, that potentially operate at once, which are: research cycle, interrogative cycle, types of thinking, and dispositions. The authors adapted the research cycle from the PPDAC model, proposed in 1994 by MacKay and Oldford, which is comprised of five parts, named Problem, Plan, Data, Analysis, Conclusions (PPDAC), which function sequentially according to the process of conducting an empirical statistical inquiry.

The interrogative cycle is a generic thinking process in constant use when solving statistical problems. This cycle consists of five elements named Generate, Seek, Interpret, Criticize, and Judge. Wild and Pfannkuch (1999) classified types of thinking in two categories, some of them are common to all problem-solving and others are inherently statistical. Dispositions, identified during interviews with statisticians, are referred to as personal attitudes that affect entry into a thinking mode. Here, only the two elements relevant for this research are described.

Among types of statistical thinking is the recognition of need for data, described by Wild and Pfannkuch (1999) as a statistical impulse. This thinking propels making decisions based on data deliberately collected for this aim after recognizing that personal experiences or anecdotal evidence are inadequacies to make these kinds of decisions. Among general types of thinking applied in a statistical context, familiar to all problem-solving issues, *strategic thinking* is activated to answer: What will the team do? How will the team do it? What difficulties or limitations could emerge? For problem-solving, it is mainly useful in the planning phase of the research cycle. The authors also mentioned that this type of thinking is restricted in quality and effectiveness for factors external to the thinker, such as resource constraints or misunderstandings and gaps in the transmission of essential information during communication among participants of the inquiry, or factors are internal to the thinker, for example, the lack of knowledge, preconceptions, attitudinal aspects, and inadequate communication skills.

Chance (2002) presented a vision of the implications of incorporating these components in future statistics instruction. She suggested instruction on ways to promote the development of six mental habits in future statistics, and also offered options to assess its achievement. These habits include,

> consideration of how to best obtain meaningful and relevant data to answer the question at hand; constant reflection on the variables involved and curiosity for other ways of examining and thinking about the data and problem at hand; seeing the complete process with constant revision of each component; omnipresent skepticism about the data obtained; constant relation of the data to the context of the problem and interpretation of the conclusions in non-statistical terms; and thinking beyond the textbook. (p. 4)

Chance concluded that the development of these different types of statistical thinking is multipurpose. She also mentioned the relevance of promoting in each citizen the comprehension of significance and need for proper scientific research.

Arnold (2013) drew attention to the lack of clarity for the academic community about the formulation of questions. She also showed the importance of using precise language and wording for constructing questions. According to her, in relation to the context of the statistical investigation cycle, there are four different question purposes (investigative, survey, analysis and interrogative questions) clustered by its nature: (1) "Question posing arises as a result of having a problem that needs to be addressed using a statistical investigation" (p. 19); which may be produced for two possible purposes: to be answered using data (investigative questions) or to get the data (survey questions); (2) "Question asking is a continual spontaneous interrogative process" (p. 30); which could be issued for two possible purposes: to choose methods or representations for data description or making inference (analysis questions) or to check each stage (and their relations) within the PPDAC cycle (interrogative questions).

Based on four exploratory teaching experiments with students (ages 14–15), Arnold (2013) concluded that active reflection is one way for teachers to model students' thinking. The steps of this process could be: first, the teacher (and/or students) writes an investigative question on the board; after that, the learner actively reflects on it, looking to improve it, and writes a new version of the question; the learner reflects on it, again, as many times as be necessary; and ends when wording seems to be correct and complete. If the learner needs help, the teacher can think out loud as he/she considers the problem because "Both active reflection and thinking out loud appear to support concept development and the development of statistical thinking routines" (p. 240).

2.2. RESEARCH APPROACH IN TEACHER EDUCATION

Theoretical frameworks about teacher knowledge for teaching statistics. In 2007, two models were proposed that included a research approach explicitly among the components. Each model merged the component of teacher knowledge of statistics teaching differently.

The model proposed and partially tested by Burgess (2007), drew on Wild and Pfannkuch's model of statistical thinking and the work of Hill et al. (2004), and Ball et al. (2005) about categories of teacher knowledge for teaching mathematics. Burgess (2007) proposed a matrix whose rows are the dimensions of the Wild and Pfannkuch model and whose columns are the following teacher knowledge categories: Common Knowledge of Content, Specialized Knowledge of Content, Knowledge of Content and Students, Knowledge of Content and Teaching. Burgess (2007) pointed out the advantages of carrying out the entire research cycle as a learning strategy, comparing to doing *reduced research* in the classroom, and reported the challenges that apply to the teacher.

The theoretical framework proposed by Groth (2007) was comprised of two kinds of knowledge, common and specialized, from two sources according to its nature, mathematical or nonmathematical. The author highlighted differences between teaching statistics and mathematics, and the focus on activities linked to the role of statistics in research methodology.

Observational studies. In the decade after merging these frameworks, various research studies examined the contribution of the research process in teacher education. The following three examples showed the potential for or observed linkage between the participation of teachers in research and its benefits for their professional development. Also, the authors mentioned some difficulties in the phase of planning, which is a focus of the educational experience of this classroom research.

González and Chamoso (2015) analyzed the performance of 120 prospective primary school teachers in Spain who attended *Mathematics and its Teaching*. They designed and executed 25 projects, one for each group of 4–5 participants; topics were selected by each group, from a list suggested by the educators. Projects followed survey structure as methodology, using different methods for data collection. This research showed that the hardest phase for prospective teachers was to formulate the problem; they achieved intense learning by designing their survey. They concluded providing advantages of applying this approach, primarily associated with motivational aspects.

Groth (2017) observed the research process followed by two prospective math secondary school teachers (in the United States) under his guidance as a statistics education researcher. Groth (2017) focused on the developmental potential of mistakes, as long as these can become learning opportunities and sources of discussion. According to the research background, *the productive mistake* was adopted from engineering research, and is distinguished from other kinds of errors because of its possibility for leading to learning. This productive mistake is characterized by promoting brain growth because it invites reasoning in an alternative way, which is only explored when this error is observed. Finally, Groth drew attention to the learning experience, which required participants to reflect on their teaching practices and to debate issues with their tutors.

Green et al. (2018) analyzed aspects of each stage of solving the statistical problem process in nine theses, from a Masters program for in-service mathematics teachers, who taught 6th to 8th grades in the United States. The sample of dissertations was selected from classroom research conducted during the *Teacher as Scholarly Practitioner* course. Each participant created an action research project and, to that end, wrote a paper with his/her results, applying different analysis methods (qualitative, quantitative, or mixed). The authors were mainly interested in projects that used statistics (descriptive or inferential) for data analysis. Among the findings, they mentioned the math teachers' weakness in research planning and data collection. As an example, they observed confusion between randomization and random sampling. The participants used quantitative variables when it was better to use qualitative variables or forced articulation of quantitative analyses to apply a mixed method. There was a tendency to include quantification to report results.

The problems exposed in this research are still valid and typical for many countries, noticing that observational studies were from the last five years, although knowledge of teaching frameworks have existed since 2007.

3. METHOD

To observe the evolution of recognition of need for data in the math teachers involved in the research, the methodology was participatory action research with a qualitative analysis approach, according to descriptions given by Cohen et al. (2018).

Description of participant group. This experience was carried out from September to November 2018 in the course named *Teaching of Statistics*. This practice was an optional subject without previous requirements in a graduate program aimed at in-service secondary school teachers. It was called Master in Exact and Natural Science Teaching, whose objective was to improve his/her disciplinary knowledge. In particular, this course provided teachers with tools to promote the development of *random thinking*[1] in their students (aligned with the language of MEN, 1998). Weekly classes were held in sessions of two contact hours and two online hours, which were complemented by autonomous work.

At the beginning of the academic period, the course was composed of twelve math teachers. After three weeks, two of them dropped out; in consequence, the participant group had ten members who completed the course.

On the first day of classes, the twelve teachers initially enrolled in the course answered two questionnaires. One asked about their practices for teaching statistics and their motivation with the course (all open questions). The other survey asked for their level of disciplinary knowledge (open and closed questions). The second showed that the majority had high performance in the statistical procedures evaluated, with some inaccuracies in conceptual aspects.

Everyone had between 5 and 15 years of professional practice as secondary-school mathematics teachers (students from 11 to 17 years old). Three of the participants used real data, which they downloaded from a web page, for contextualized teaching. They worked in schools whose pedagogical paradigm was project-based learning (PBL); for that reason, they had a particular interest in deepening their understanding of implementing PBL practices in their teaching. This approach pursues the same intended educational purposes with statistical problem-solving as a teaching strategy. Both approaches share motivational advantages, difficulties, and challenges for the teacher (Blumenfeld et al., 1991).

[1] The Colombian curricula of Mathematics for Elementary and Secondary School is organized according with five types of mathematical thinking, named (MEN, 1998): numerical, spatial, metric, variational and random. Each one is associated with a branch of Mathematics; *random thinking* is linked to Probability and Statistic basic knowledge.

At the beginning of the course, together (teachers and educator) decided two aspects: (1) They will go through project-based learning from the role of students (in one part of the course, 8 to 10 weeks); and (2) A learning objective would be to develop the recognition of the need for data.

The project was proposed conjointly by twelve math teachers, at the beginning. However, after five or six weeks, the process was carried out in groups of three to four members. This decision was taken mainly due to communication difficulties among them and differences in aroused interest level for being involved in the project. Moreover, two dropped out in the first weeks because they did not have enough time to make complementary tasks.

Description of formative experience structure. Formative experience had three moments linked to the PPDAC stages, partially following suggestions of Chance (2002). The first two moments were for Problem and Plan (PP) stages, and third moment set the other stages, Data, Analysis and Conclusions (DAC). Throughout the formative process, the teachers presented various written reports.

In previous classes, before beginning this part of the course, the teacher educator asked the twelve teachers to define among them a problem situation that might be of common interest. First classes were for establishing the problem, posing an interrogative question, and project determining objectives. At the same time, via open access methodology, official surveys for the educational sector were analyzed. The second moment was associated with the Plan stage, mainly focusing on questionnaire design, which involved identifying statistical, contextual, and methodological characteristics of the variables involved. Furthermore, identifying how measurements are reflected in the data and how the data are articulated.

The third moment was linked to DAC stages of the investigative cycle. The end-product was a written report by small groups, which consisted of three parts. In the first part, they summarized the procedure followed by them when conducting the project from the selection of the topic to work until showing the findings. In the second, they analyzed the elements of statistical thinking involved throughout the process. In the third, the project findings were exposed. Interpretations and conclusions were based on the evidence provided by the data collected. The teachers were required to mention which results agreed with their initial assumptions and which surprised them by differing from what the group expected.

Description of data analysis process. In this research, qualitative data derived from different sources: questionnaires applied at the beginning of the course, participant observation, personal field notes, students' reports, and online conversations saved in audio (classes' records).

Each unit of meaning was defined according with the nature of data source. For audio records and field notes, the unit was class quotation distinguish by speaker and idea; as its length was variable, transcription of each unit sometimes corresponded to a phrase and sometimes to a paragraph. For written homework (progress and final report) and responses to the initial questionnaire, the unit of analysis was each portion of student work with complete meaning, which, most of the time was one paragraph or one question.

Data were organized, analyzed, and presented by events linked to a time sequence because extracts from classes or homework completed between a couple of classes. Each participant was coded by E#, in order to facilitate identifying his/her evolution over time.

Data, analysis and interpretation were strongly merged because in action research feedback from data is used in an ongoing cyclical process. Classes were adapted over time according with students' progress. This was possible because the course calendar was flexible, and the most important issue was developing statistical thinking for these math teachers. As Cohen et al. (2018) said: "the process of [qualitative] data analysis is recursive, non-linear, messy and reflexive, moving backwards and forwards between data, analysis and interpretation" (p. 644).

This research is reported in narrative form to facilitate conveying the reflexivity on practice and making obvious the voice of both the participants and the researcher.

4. RESULTS

Now, parts of the course evolution are reported as evidence of participants' performance and of need for mentoring by teacher educators. After that, main findings related to development of the two types of thinking objective to this research are reported in a time sequence to facilitate identifying the evolution. Finally, some dispositional aspects that affected the progress are mentioned.

4.1. PERFORMANCE

The first moment of the statistics course was the most extensive in time and rich in formative experiences. The problem situation was quickly selected. One of the teachers proposed to analyze the impact of a Bill, announced days before in the media, related to prohibition of bearing and use of mobile devices in schools. Everyone agreed that it was an interesting common issue to them and pertinent to the aims of the course. Also, that the study scope would be exploratory, and a survey would be an appropriate research methodology for this situation, following the structure suggested by Cohen et al. (2018). It is interesting to note that the teachers started to speak about variables and open or closed survey questions; without having restricted their problem.

The teacher educator explained that, first, the teachers had to define the project's aim and invited them to pose an investigative question or a general objective for their project. Related to the problem formulation, emerged the following proposals:

> *E1: Measuring or knowing the opinion of the scholar community about the advantages and disadvantages of the Bill. (first class)*
> *E2: Characterizing perception of the advantages and disadvantages of using cell phones into the classroom. (first class)*

The group debated possible question formulations. When some questions were chosen, the educator questioned them about whether the answers could arise from theoretical studies, empirical studies published in other countries, or their personal experiences. To answer these interrogative questions, participants explored publications in the media and in academic journals. By one side, the closest antecedent to their problem was a similar initiative in France, of which there were no published related studies. On the other side, "the advantages and disadvantages of cell phone use in the classroom" could be obtained by reviewing the literature, taking into account that the use of Information and Communication Technology (ICT) in the classroom had been promoted in recent decades and there are papers related to applications for pedagogical purposes. Other actions of the teacher educator were to ask the meaning of each verb proposed and if this verb agreed with their study interest. Next, she asked participants to identify in each of these sentences what would be the object of study and target population.

In the next class, the proposals for problem formulation were reflected in writing a general objective. The wording of E3, accepted by the majority, was: "Determine the impact that could be generated by the implementation of the law that seeks to prohibit students of Basic and Middle School from using electronic devices in schools." Again, the educator asked the meaning of some words or phrases and, if agreed with a research interest, dividing the paragraph to draw attention to some aspects that could have different interpretations, such as "impact," "law implementation," "use of electronic devices in schools."

After debating this objective, two new wording options were proposed with partially different purposes:

> *E4: Determine uses that youngers give to electronic devices in the school time into different Schools of Bogotá to find some relation between these uses and lack of concentration in school activities. (second class)*
> *E2: Determine the impact of using in school time of electronic devices by students of different Schools of Bogotá over school activities." (second class)*

The teacher educator invited the teachers to come back to read each one of the four articles of the Bill. Then, they had to reflect if the wording corresponded to their initial purpose of "measuring the impact of Bill implementation." Again, emphasis was on meaning and linkage of words and phrases that they used and on possible interpretations, as well proposed objectives as the set of articles in the Bill.

In the next class, the wording was: "Determine the possible impact that could be generated by the implementation of the second article of the Bill that seeks to prohibit students from Kindergarten to 11th

the use of electronic devices in the classroom from the teachers' point of view." (joint work between E5 and E6, third class).

To analyze the adequacy of this wording and to what extent the statement reflected the research interests of the group, together the teachers read and deeply examined the wording of the second article in the Bill:

> *Article 2. It is prohibited using mobile phone devices into classrooms of all schools at preschool, primary school, secondary school, and middle level. This restriction will apply as students, as teachers.*

This conjoint analysis made it possible to more clearly delineate the problem, of common interest to all, and what would be its target population. After some adjustments, the final version of the general project objective was (joint wording among E4, E7 and E8, third class):

> *GO: Inquire about the impact that could be generated by the implementation of article 2 of Bill 099. This article seeks to prohibit the use of mobile phone devices within preschool, basic, and middle school classrooms in some Schools of Bogotá and surroundings.*

The definition of the problem question required three weeks because the teachers only debated issues raised when in contact sessions (the only space where all of them to speak for themselves) and various participants did not do the homework suggested by the teacher educator. Moreover, during online sessions (virtual classroom), faults of connectivity obstructed active participation by everyone. Those sessions were analyzed for the procedural issues of planning, taking into account survey studies published by the National Administrative Department of Statistics (DANE, Colombia). In other countries, the organization is known as the National Bureau of Statistics (Instituto Nacional de Estadística). These studies helped to identify relevant elements of strategical thinking and guided the relevant steps to follow in their project.

The specific objectives were defined in the first two weeks and were adjusted in the following week when the discussion on relevant variables and questionnaire design began. To establish goals was result of the progress made during the problem formulation. The final wording for the specific project objectives was:

> *O1: Characterize the use that students of secondary school give to mobile phone devices in the classrooms of some educational institutions.*
>
> *O2: Characterize the use that pre-school, primary, and middle school teachers give to mobile phone devices in the classrooms of some educational institutions.*

At the end of the first moment of the study, a balance of the learning achieved among the participants was made.

In the first class of second moment, after suggesting some sociodemographic variables, shared in social studies, the teachers began to define variables operationally by formulating potential questions for the questionnaire with their possible answers, instead of setting them conceptually. The variables suggested by E2 were: Mobile device carrying in the School, use of the mobile device in the classrooms of School, time of using a mobile device in the School, acceptance of using mobile device in the School, restriction of use, type of link with the School (Student, Teacher), socio-economic level, schooling. It is needed to say that E2 had a little more experience in empirical studies because of their professional training (chemical engineer).

For the second class of the second moment, some teachers proposed questions taken from other studies or from questionnaires with similar topics, which they consulted on their own initiative. This information promoted a brainstorm, which was guided by the teacher educator to encourage learning. The third version of the proposed variables is shown in Appendix 1, accompanied by some of the responses to questions asked by the educator.

The teacher educator in these four sessions (two contact and two virtual) asked them about aspects related to the need of each variable, such as: Are these variables pertinent and relevant? Is there any leftover? How do you think they will distribute in the target population? Will there be other variables related to the problem? After having a set of questions established, with this set of variables or questions, are all the objectives proposed for this project achieved?

This second moment led to having three collection proposals, one for each group of 3 to 4 teachers. Each questionnaire was relatively complete for the study purposes, and its application proceeded because time was running out for the stages remaining. These final questionnaires are replicated in Appendix 2.

To end, the teachers showed respectable performance in DAC investigative cycle stages (third experience's moment) because, in their classroom practices, they were accustomed to interpreting in context the results of procedures they applied to data sets available from various sources (workbook, web page or something similar).

4.2. DEVELOPING "RECOGNITION OF NEED FOR DATA"

During the first class, it was observed that the participants associated developing recognition of need for data with proposing a questionnaire to collect data, and linked data with responses to survey questions. These math teachers overlooked the relevance of defining a problem question before defining research objectives and deciding on the target population. Repeatedly during the first weeks, they began to propose variables and survey questions, without having yet limited the problem. They were primarily focused on questionnaire design. These practices evidenced a low level of strategic thinking, as well as the need to distinguish the types of questions involved in an empirical research, one of the difficulties mentioned in Arnold (2013).

It was noticed that there was a difference in the development of the recognition of need for data when working with a reduced project in contrast to carrying out an entire statistical investigation. Three of the participants had contextualized teaching of statistics in their professional practice; their strength was in data analysis because, in general, using secondary sources (open database) in projects that worked with their students. Their view of data was linked to their classroom practices with reduced projects; for them, from a one-dimensional approach to the matrix (usually downloaded from the internet), each datum corresponds to the response given by an individual to a survey question. In this sense, need for data was, for them, the need to obtain answers to survey questions.

In the reduced projects the first steps of the research cycle were skipped. Now, these teachers had the opportunity to focus deeply on the problem posing and planning challenges, and to recognize the link between data and the investigative question. For this, the teacher educator guided the continuous reflection on each step followed by the participants, through interrogative questioning. These reflections helped to delineate the problem because the teachers realized that some of the questions asked could be answered with a literature review, and others exceeded the purposes of the course. When they were sharing information from the background check, it was the first moment in which the need to look for their data was evident, from the Colombian context. That was necessary to answer their questions and generate conclusions useful as an argument for or against the approval of the Bill.

The identification of a target population had been mentioned since the first class of the course. Because of their reflections, the teachers realized that "the scholar community" denoted a vast population; the goals of the course would be exceeded in terms of the possibility that we could access that community, which included several subpopulations. Therefore, the target population was restricted to teachers and students linked to the schools where the participants worked.

Everyone agreed that there was a common target population for the group. However, differences in characteristics of their students and their teaching practices (including the use of technology) were evident; especially when they were designing the questionnaire, associated with some of the proposed variables and the answers to "How do you think they will distribute in the target population?" This situation allowed them to realize that need for data was differentiated, despite seeking to respond the same investigative question, according to the characteristics of the target population. It promoted additional discussions about variability, subpopulations, stratified studies, and the scope of exploratory studies.

The second moment showed other weaknesses, as in strategic thinking as in recognition of need for data, related to their previous work with reduced projects from secondary sources. As explained in Section 3, this moment was focused on the planning stage, mainly on the design of the questionnaire.

Initially, participants were unaware of the relationship between the structure of the questionnaire and the objectives of the project and the relationship between the survey questions and the investigative question. These math teachers associated data sets with a matrix and the questionnaire with a set of survey questions. The label of each question identified its column (variable); therefore, the label of each survey question was the link between the study and the data.

In the first two classes of this second moment, the math teachers began to operationally define variables, posing potential survey questions with their possible responses instead of conceptually defining or relating to the proposed project objectives. They were more concerned whether the survey questions were open or closed, qualitative or quantitative, than being concerned about their relevance to the study or the target population.

It was sought to turn the typical error (to confuse variables with questions) into a learning opportunity. For each proposed survey question, the teacher educator asked interrogative questions related to analyzing the associated variable; to which objective it was linked; if its intent was similar to that of another question; if it was complementary to another question; or its feasibility of implementing in schools. This inquiry made it easier for the teachers to identify each variable, its role in the study, its need for measurement, its relationship to other variables and data clusters. It also allowed recognizing the project constraints to which helped to adjust the objectives.

The successive reflection led to identifying for the study the main and secondary variables, based on their contribution to achieving the project's objectives (GO, O1, O2) and their relevance for each subpopulation. Accordingly, the participants realized that data needed for their projects could be different from one group to another, and that this need was closely related to their vision of the problem. The collection instruments designed by each group (from 3 to 4 participants) served the study purposes according to identified subpopulations. These groups of 3 to 4 members were confirmed as the design of the questionnaire advanced for two reasons: peer affinity, and differences in the target populations to which they had access.

At the end of the second moment of this experience, the participants had recognized that, in many studies, the investigative question required multivariate data, because the problem situation is multidimensional and the best way to approach it is to link one (or several) variable(s) with each dimension. Furthermore, they recognized that different data are sometimes needed within the same study, according to subpopulations and questions posed.

Measuring with validity and reliability is an essential challenge in a social investigation, especially when the object of research is a construct, as was the case in the project proposed by these math teachers. During this part, the teachers showed how their incomplete understanding of the problem or their preconceptions regarding the use of mobile devices in the classroom, influenced on the identification of variables and their possible measurement. This confirmed outcomes and concerns expressed by Wild and Pfannkuch (1999).

Consequently, there was a difficulty that teachers perceived in the first two moments the situation that their students will also go through when they implemented project-based learning in their classrooms. The participants in this study not only developed this type of thinking, but they also identified some elements of the pedagogical components associated with individual teacher’s knowledge.

4.3. DEVELOPING OF STRATEGICAL THINKING

Lack of strategic thinking to solve a statistics problem in the planning stage was evident when participants supposed that the first task would be to create a questionnaire for data collection. Teachers overlooked the relevance of limiting an investigative question, defining research objectives, and determining the target population beforehand. All of them had the skills for planning from a teaching point of view from their experience as in-service teachers. They scheduled their classes and established deadlines for topics and assessments, following guidelines of his/her school. In this sense, it was emphasized that low level strategic thinking is only referred to in the planning stage when they were solving a statistics problem.

During Problem stage’s classes, difficulties mentioned in previous research were evident: lack of understanding (of learners) about how the choice of problem question affects all stages of the project (Heaton & Mickelson, 2002, cited by Groth, 2007); formulation of very general questions, without specifying measurable variables (Konold & Higgins, 2003, cited by Groth, 2007); imprecise or incorrect use of language (Biehler, 1997; Pfannkuch et al., 2009, cited by Arnold, 2013); low ability to pose a good investigative question, as well as lack of differentiation between investigative and survey questions (Arnold, 2013). Analysis of these situations and the positive effect of the active reflection of the teachers to overcome these difficulties is presented below.

The problem situation was selected quickly. However, it was a challenge to promote comprehension of the *problem as a study object*. Teachers repeated their practices in this project when using secondary sources: after identifying an issue, focus on “go-to data.” At this moment, the proposed problem was extensive, and interpretations of each article of the Bill differed from one to another teacher. This issue will be seen later when some evidence is presented. The intervention of the teacher educator was necessary to demonstrate the relevance of the problem stage. This involvement was done by asking questions of each of the teachers and promoting group discussions linked to each definition that restricted the study during classes.

The responses given to teacher educator’s interrogative questions showed different stances concerning the aims of the study. This evidenced that the teachers realized that different wording impacted beyond a writing change. Underlying the projects imagined by E1 and E2 were different intentions, which also differed from the purposes of their peers, reflecting a diversity of vision about the problem by these teachers.

During debates, another difficulty observed was an inability for the teachers to leave aside their preconceptions about the convenience of Bill implementation. The wording of E2 and E4 for the second class showed their preconceptions and stances on the use of mobile devices within the classroom or school. The joint analysis among the teachers about the article in the Bill, from answering the interrogative questions, facilitated defining more clearly the problem of common interest to all and what would be its target population. Establishing specific objectives was the result of the progress achieved during investigative question posing. Adjustments arose when participants realized their restrictions on accessing the target population that they initially intended, due to logistics and time constraints; conditions that appeared gradually during the design of the questionnaire.

At the end of that part of the course, a consensus was reached about the lessons learned, and it was verified that these math teachers became aware of some issues. For example, the importance of the preparation of each project stage: identify subtasks at each stage, integrate a functional work team, distribute responsibilities, anticipate problems and plan how to avoid them, and predict the effect on planning due to project execution limitations. It was noticed that their self-confidence to lead a project with their students themselves remained low or medium. The teachers said that they still lacked the expertise to deal with the different kinds of problems that might be of interest to their students.

The teachers (participants of this study) replicated situations that could occur with students. Some of them had a low level of agreement among them about what they wanted to achieve and low levels of communication outside the classroom. They also found that the literature and other sources reviewed to help them delineate the problem were sparse and they needed instructions to follow (they asked for a template or a guide). These situations allowed that during the classes, the teacher educator showed the origin of the difficulties and the way that they could face them in their future teaching practice. Moreover, the teachers recognized the pros and cons of using secondary sources compared to conducting research to collect other data.

In conclusion, planning was an erratic practice that required the intervention of the educator. First, the assistance was advisory due to the tendency of the participants to seek data and their lack of familiarity with the research cycle. Second, assistance with the resolution of conflict and disagreement was needed because none assumed the leadership of the group, and some did not recognize the valuable knowledge or information provided by their peers.

4.4. LEVELS OF ACHIEVEMENT

The achievements of this educational experience were differentiated among subgroups of participants, as described in this section.

Three math teachers dedicated the extra-class time planned to complement the topics, contributed to the discussion from their knowledge or from their genuine interest in clarifying concerns related to the process or content. These participants really wanted to deepen their understanding of project-based learning to implement it in their classrooms in a more complete way, and to select authentic learning contexts for their students. They had experience with asking questions in an adapted cycle for using secondary sources (DPPAC, Arnold, 2013), but lacked experience with posing questions in an original investigative cycle (PPDAC). They showed, from the beginning, a high level of statistical knowledge associated with data analysis, but they lacked integration with the context in a more conceptual sense.

These three teachers achieved substantial development of strategic thinking and recognition of need for data.

Three participants met only the minimum requirements for successful completion of the course. They rarely completed the suggested readings, and their comments were empty during live or online sessions. Sometimes they repeated observations which denoted a lack of attention to the class. Their development of strategic thinking and recognition of need for data was very low.

The other four participants dedicated the extra-class time planned to complement the topics in the first four-five weeks, but that time decreased for the last weeks. Their contributions to the debates were similarly affected. However, they kept interest in understanding the process and its foundation until the end of the course. The reduced time committed caused a lack of continuity in the reflections on the problem, and the progress of the project. These factors affected development of the two types of thinking, which are valued at an intermediate level.

The overall balance of the educational experience was positive. Half of the participants kept their interest in applying active learning strategies for statistics training or statistical thinking development. One of them, based their Final Masters work on problem-based learning, three to project-based learning, with another to implement this strategy in her classroom during the following school year (without a link to a Master program).

Next, limitations of the research associated with the dispositional component are mentioned, only the first one was common to all participants.

The teachers felt anxiety during problem and plan stages. The insecurity they felt for facing an unknown process caused them discomfort. Leaving their comfort zone was a challenge. Only a few were proactive, getting involved in the project formulation. The others asked for a template or a guide that will make it easier for them to perform each task. They wanted to be given a procedure or an algorithm that would lead them to a correct response.

The teachers' engagement decreased when they realized that each statistical problem has a different solution, depending on the study objectives. They found that although there are patterns for statistical problem solving the first steps are unique. This discovery generated some disappointment about the real possibility of applying project-based learning holistically. This pedagogical strategy implies much extra-work be put in by math teachers and their partners, teachers of other disciplines involved in a potential project, given that most of the stimulating problems are interdisciplinary. For each new project, the team of teachers must learn about the context for an accurate understanding of the problem, which is to be understood as a study object rather than as an excuse to apply procedures. Only after that, the team of teachers and students could inquire about the ways of measuring.

Finally, the time available for extra-class activities affected the participation of teachers. Two canceled in the first three weeks of the course (initially, they were 12 enrolled). Four began with the expected dedication, but it decreased as their job duties increased for ending the school year.

5. CONCLUSIONS

This research aimed to develop recognition of need for data in a group of teachers participating in a Masters degree program. This development was evidenced, as well as that of strategic thinking, through the active participation of teachers in conducting a survey proposed by the participants and delineated under guidance of the teacher educator, which was linked to a real-life context through learning about project-based learning. Besides, implications for statistics teaching were analyzed.

The experience was successful. All the steps on the "Problem" and "Plan" stages promote the development of the recognition of need for data and strategic thinking, mainly mediated by the participants' reflection. The result was differentiated in these math teachers according to their experience in developing reduced projects, their engagement, and their active participation.

This experience encouraged teachers to develop some of the mental habits suggested by Chance (2002) for future statisticians: think on the best way to obtain relevant and meaningful data to answer the research question; regularly reflect on the variables involved; and continuously relate data to problem context, in non-statistical terms. Recognition of the potential effect of their preconceptions on the process was considered a first step to promote skepticism concerning data obtained. In the final reports, some participants evidenced results contrary to their expectations and thus were reported; while others persevered in their stances, although data was inconclusive in that regard.

In the information age, access to databases with different characteristics has generated a misconception among citizens. That is, any data are available and easy to obtain, as expressed by some of the participants at the beginning of the course. Half of these participants taught statistics by applying algorithms to data of a problem solved (already published) that was accompanied by a situated interpretation, which involved seeking contextualized and meaningful learning in their students but neglecting the problem-solving process as a whole; practices concordant with those reported by Stuart (1995).

The educational experience allowed the teachers to realize that there were questions of interest. They further realized that for a community with local problems, whose answers are not obtained with the available sources, data collection related explicitly to those problems was required. Participating as learners allowed the teachers to experience difficulties in obtaining quality data; they illustrated breaking with the idea of quick and accessible information and generated an awareness of the relevance of the research cycle and the need to develop strategic thinking to achieve the planned purposes or to answer real problems.

This study replicated advantages such as those observed by Marriot et al. (2009) and González and Chamoso (2015). However, it showed limitations related to the difficulty in defining the problem question, low intrinsic understanding of the problem, communication failures between peers, and demotivation for not quickly observing results. It drew attention to the subject being highly motivating because the topic was actual, but its real relevance was questioned when the teachers felt limited in their suggestion capacity. An observed difficulty, not reported in previous research, was time availability. Possibly because in the background, the target population was university students, while in-service teachers work full time in their schools and, in general, have family responsibilities.

Moreover, the results of the analysis allowed us to conclude that the development level of strategic thinking and recognition of need for data in these teachers was affected. This result was due to diversity in personal levels of disciplinary knowledge, participation, time allocated to extra-class activities, engagement, and interest. It should be noted that, from the educational point of view, project-based learning as an active learning strategy requires high and engaged participation to build knowledge or develop skills (Blumenfeld et al., 1991).

An added value of this educational experience was that the mathematics teachers involved expanded their vision of statistics. At the beginning of the course, they considered it as a tool that provided them with procedures for data analysis. In the end, they recognized its relevance throughout the research process and its impact on methodological decisions.

6. DISCUSSION

As mentioned in the introduction, in various countries, there is still a need for teachers’ developing components of statistical thinking. When they do, they feel confident in carrying out active learning practices in their classrooms. It is often expressed that mathematics teachers focus their statistics teaching on algorithmic procedures. However, concerns arise about the real possibility of achieving in-depth conceptual knowledge without having contact with real-world applications. This questioning was one of the bases for frameworks proposed by Burgess (2007) and Groth (2007), as well as for various initial or continuous educational strategies proposed by other authors. This research was intended to contribute to this regard, especially for Spanish-speaking teachers and Latin American idiosyncrasies, who tend to miss related publications with their difficulties, either due to differences in context or language barriers. Note that in Colombia as other Latin American countries, a high percentage of schoolteachers have low technical English reading levels, and the main academic papers are published in English.

Recognizing need for data is essential for a teacher, who intends to implement project-based learning for statistics training, because each project is unique with peculiarities that come from the diversity of problems in our world. Data reflect variability inherent to populations and to the different ways of measuring characteristics that may be of interest, given our multifactorial and multivariate universe.

Data answers some problem questions and could respond to related questions, but not other questions. Recognition of need for data implies being aware that each question can be answered by its data. Moreover, each data set reflects a particular story according to its context. Therefore, trends or patterns observed in a data set will account for population realities, not just any population. Data available on the web may correspond to a community that is very different from the students' interest population. As they are being trained as future citizens, members of a society in a local context, teachers should be aware of the limitations that entail the *reduced research*.

This educational experience is aligned with the reflections of Green et al. (2018) about experimentation relevance and schoolteachers' contact with learning opportunities associated with each stage of the research cycle. Also ratified was their conclusion on the need to expand knowledge development research, both disciplinary and pedagogical, of mathematics teachers for statistics teaching.

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APPENDIX 1.

OUTLINE OF GROUP 1 PROPOSAL FOR STUDY VARIABLES, WITH THE OBJECTIVE TO WHICH EACH VARIABLE RELATES AND ITS OPERATIONALIZATION IN THE QUESTIONNAIRE

Variable	Project objective (see section 4.1) linked to the variable	Question and possible answers
School	Socio-demographic	Name of School (list of 12 schools where participants were involved)
Grade		Grade: 1. 6th 2. 7th 3. 8th 4. 9th
Age		Age: (Open question)
Socio-economic level		Socio-economic level: A. 1 B. 2 C. 3 D. 4 E. 5 F. 6
Gender		Gender: A. Female B. Male
Carry cell phone	O1 and O2	Do you have a cell phone? A. Yes B. No C. I use other technologic devices
The utility of the cell phone device	O1 and O2	For what do you use a cell phone at school? (Open question)
Frequency of use	O1 and O2	How often do you use the following applications/services on your cell phone? (tablet) • Photo/video camera • Music player • Games • Calculator • Clock • Schedule • Calls • Text messages
Internet availability	O1 and O2	Do you have an internet connection on your cell phone? A. Yes, always B. Only via Wi-Fi C. No
Applications	O1 and O2	How often do you use the following cell phone applications with internet service? • Browsers • Social networks (Facebook, Instagram, Snapchat) • WhatsApp • Geo-location applications (Waze, Google Maps) • YouTube or music players • Application download • Mail

<table>
<tr><td></td><td></td><td>If you use another application with an internet connection, indicate which one it is. (Open question)</td></tr>
<tr><td>Classroom uses</td><td>O1</td><td>Do you use your cell phone to do your homework?
A. Often
B. Sometimes
C. Little
D. Never

Indicate devices and applications that you use to make the scholar tasks:
• Photo/video camera
• Calculator, Schedule or Voice Recorder
• Browsers
• Social networks
• WhatsApp
• Maps / GPS J.
• YouTube
• None
• Other:

Have your teachers used the cell phone for works or school activities?
A. Yes
B. No
C. Sometimes

If yes, on the previous question, in which subject(s) have you used them?
A. Spanish Language and Literature
B. Foreign Language
C. Arts
D. Social Sciences, Geography, and History
E. Natural Sciences
F. Mathematics
G. Physical Education - PE
H. Technology
I. Ethics
J. Music
K. Other

Specify in which subject you think it is more enjoyable to use the cell phone to make school tasks:
A. Spanish Language and Literature
B. Foreign Language
C. Arts
D. Social Sciences, Geography, and History
E. Natural Sciences
F. Mathematics
G. Physical Education - PE
H. Technology
I. Ethics
J. Music
K. Other</td></tr>
<tr><td></td><td>GO</td><td>What do you think are the advantages of law enforcement…?

What do you think are the disadvantages of law enforcement ...?</td></tr>
</table>

APPENDIX 2. QUESTIONNAIRES APPLIED BY GROUP 2 TO EACH SUBPOPULATION (STUDENTS AND TEACHERS)

The questionnaires were prepared with Google Forms, for inclusion in this article they were transcribed into the Word file, which entails changes in the display of the form.

Questionnaire to students:

Dear student: Below you will find some questions to know the use that you give to the cell phone in the school. We appreciate your honest answer to each of the questions. The information collected here will be used for academic purposes.

The sign * means that this question is required

General Information

1. Age * ___________

2. Gender * (Choose only one option).

☐ Female ☐ Male

3. Type (or Nature) of School * (Choose only one option).

☐ Private ☐ Public

4. Grade Level * (Choose only one option).

☐ 6th
☐ 7th
☐ 8th
☐ 9th

5. Socio-economic Level * (Choose only one option).

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6

Carry and utility of the cell phone device at school.

The following questions are intended to know about using of cell phone at school and during class time

6. Do you have a cell phone? * (Choose only one option).

☐ Yes ☐ No

7. Is allowed using cell phone at school where you study? (Choose only one option).

☐ Yes ☐ No

8. Do you carry your cell phone at school? (Choose only one option).

☐ Yes ☐ No

9. For what do you use your cell phone at school? *

____

10. Indicate devices and applications that you use most frequently * (Select all the options that apply).

☐ Photo/video camera
☐ Music player
☐ Games
☐ Calculator
☐ Clock
☐ Schedule
☐ Calls
☐ Text messages

11. Do you have an internet connection on your cell phone? * (Choose only one option).

☐ Yes, always
☐ Only via WiFi

- [ ] No

12. Do you use the following cell phone applications with internet service? * (Select all the options that apply).

- [ ] Browsers
- [ ] Social Networks (Facebook, Instagram, Twitter, Snapchat)
- [ ] WhatsApp
- [ ] Geo-location applications (Waze, Google maps)
- [ ] YouTube or music players
- [ ] Application download
- [ ] Mail

Classroom devices and application uses

13. Do you use your cell phone to do your scholar tasks at school? * (Choose only one option).

- [ ] Often - [ ] Sometimes - [ ] Never

14. Indicate devices and applications that you use to make the scholar tasks * (Select all the options that apply):

- [ ] Photo/video camera
- [ ] Calculator, Schedule or Voice Recorder
- [ ] Browsers
- [ ] Social Networks (Facebook, Instagram, Twitter, Snapchat)
- [ ] WhatsApp
- [ ] Maps / GPS J.
- [ ] YouTube
- [ ] None
- [ ] Other

15. Have your teachers used the cell phone for school activities? (Choose only one option).

- [ ] Yes - [ ] Sometimes - [ ] No

16. If yes, on the previous question, in which subject(s) have you used them? (Select all the options that apply).

- [ ] Spanish Language and Literature
- [ ] Foreign Language
- [ ] Arts
- [ ] Social Sciences, Geography, and History
- [ ] Natural Sciences
- [ ] Mathematics
- [ ] Physical Education - PE
- [ ] Technology
- [ ] Ethics
- [ ] Music
- [ ] Other

17. How much do you consider that the use of cell phones facilitates your learning? (Rate your answer on a scale of 1 to 10; 1 represent the least level) * (Choose only one option).

1 2 3 4 5 6 7 8 9 10

18. Is cell phone bearing a distracting factor for you or your classmates? * (Choose only one option).

1 2 3 4 5 6 7 8 9 10

19. Is cell phone use a distracting factor for you or your classmates? * (Choose only one option).

1 2 3 4 5 6 7 8 9 10

Bill
If there were a law, similar to this bill: Article 2. It is prohibited using mobile phone devices into classrooms of all schools at preschool, primary school, secondary school, and middle level. This restriction will apply as students, as teachers.
20. Do you agree with approval this bill? * (Choose only one option).
☐ Yes ☐ No ☐ Indifferent

21. What do you think are the advantages of law enforcement? *
____

22. What do you think are the disadvantages of law enforcement? *
____

¡Thank you!

Questionnaire to teachers:

Dear teacher: Below you will find some questions to know the use that you give to the cell phone in the school where you work.
We appreciate your honest answer to each of the questions. The information collected here will be used for academic purposes.
The sign * means that this question is required

General Information
1. Gender * (Choose only one option).
☐ Female ☐ Male

2. Do you have a cell phone?* (Choose only one option).
☐ Yes ☐ No

3. Is allowed for teachers using cell phone at school where you work? (Choose only one option).
☐ Yes ☐ No

4. Do you carry with you your cell phone during class hours (or class time)? (Choose only one option).
☐ Yes ☐ No

Utility the cell phone device at school.
5. For what do you use your cell phone at school? * (Select all the options that apply).
☐ Photo/video camera
☐ Music player
☐ Games
☐ Calculator
☐ Clock
☐ Schedule
☐ Calls
☐ Text messages
☐ Browsers
☐ Social Networks (Facebook, Instagram, Twitter, Snapchat)
☐ WhatsApp
☐ Geo-location applications (Waze, Google maps)
☐ YouTube or music players
☐ Application download

6. Which subject(s) do you teach? (Select all the options that apply).
☐ Spanish Language and Literature
☐ Foreign Language

- Arts
- Social Sciences, Geography, and History
- Natural Sciences
- Mathematics
- Physical Education - PE
- Technology
- Ethics
- Music
- Other

7. At school where you work, is allowed for students using cell phone at classroom? (Choose only one option).

- Yes
- No

8. ¿Do you propose scholar tasks in which student must be used his/her cell phone? * (Choose only one option).

- Often
- Sometimes
- Never

9. Indicate devices and applications that you use to propose scholar tasks * (Select all the options that apply):

- Photo/video camera
- Calculator, Schedule or Voice Recorder
- Browsers
- Social Networks (Facebook, Instagram, Twitter, Snapchat)
- WhatsApp
- Maps / GPS J.
- YouTube
- None
- Other

10. Indicate devices and applications that your students must be used to make scholar tasks proposed by you * (Select all the options that apply):

- Photo/video camera
- Calculator, Schedule or Voice Recorder
- Browsers
- Social Networks (Facebook, Instagram, Twitter, Snapchat)
- WhatsApp
- Maps / GPS J.
- YouTube
- None
- Other

Advantages and disadvantages

11. Since your experience, how much do you consider that using cell phones in class facilitates the process of teaching-learning? (Rate your answer on a scale of 0 to 10; 0 represent never facilitates, 10 represent always facilitates) * (Choose only one option).

0 1 2 3 4 5 6 7 8 9 10

12. Is cell phone bearing a distracting factor for your students? * (Choose only one option).

- Yes
- No

13. Is cell phone use a distracting factor for your students? * (Choose only one option).

- Yes
- No

Bill

Bill says: Article 2. It is prohibited using mobile phone devices into classrooms of all schools at preschool, primary school, secondary school, and middle level. This restriction will apply as students, as teachers.

14. Do you agree with approval this bill? * (Choose only one option).

☐ Yes ☐ No ☐ Indifferent

15. What do you think are the advantages of law enforcement? *

____

16. What do you think are the disadvantages of law enforcement? *

____

Thank you!