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REPRODUCIBILITY: DIDACTIC SITUATIONS DESIGN TO TEACH THE GEOMETRIC SYSTEM IN THE EDUCATIONAL INSTITUTION LORENZO MARIA LLERAS IN MONTERIA – CORDOBA

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Abstract

This article presents research contributions aimed at understanding academic situations generated from a specific teaching application in a curricular content. In that sense, the purpose was aimed at designing a methodological guide to build a didactic situation that would favor reproducibility in teaching the geometric system in the third grade at the Educational Institution Lorenzo Maria Lleras INEM, municipality of Monteria - Cordoba, by implementing the "GeoGebra" ICT tool, which significantly improved the scenario of teaching geometry and also encouraged teacher's reproduction of this didactic situation in other contexts.

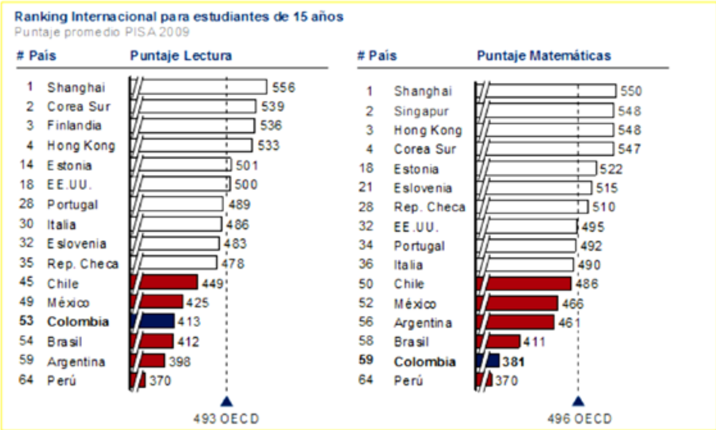
Key Words: reproducibility, pedagogical practice, didactic situation, geometry.

Introduction

Education in Colombia has faced difficulties in terms of the teaching-learning processes of educational institutions' curricular content. Clear examples are the results obtained in external tests in which students' performance in standardized tests at national and international level is low. For instance, a report by the Programme for International Student Assessment (PISA) that assessed a sample of selected Colombian students in 2009 showed unsatisfactory results for the country, evidencing students' underperformance compared with its Latin-American peers. The report ranked Colombia as number 59 out of 64 countries, with a score of 381 in the area of mathematics, 115 below the stipulated average (set at 496), as follows:

Graph 1. Pisa International Ranking 2006.

15-year-old Students' International Ranking
PISA 2009 Average Ranking



Source: OECD

Therefore, as a strategy to mitigate the aforementioned situation, the National Government implemented a program to transform the quality of education: *Programa Todos a Aprender* (PTA, for its Spanish acronym), with the objective of enhancing teachers' practices and strengthening *in situ* training by preparing school teachers at national level in the areas of mathematics and language for primary education, as per what is dictated by international and national education organizations. Thus, a range of tests is proposed and developed by the Program as valuation technique to strengthen students' learning, including the tests *Superate con el saber* and *Aprendamos*. At the same time, emphasis is placed on classroom accompaniment, *in situ* work sessions and class planning, aimed at strengthening the skills and components in the areas of mathematics and language in elementary education, established in the skills' standards, curricular guidelines, learning basic rights (DBA, for its Spanish acronym) and the curriculum.

The Educational Institution Lorenzo Maria Lleras INEM in Monteria has been targeted by the PTA in terms of the implementation of the national educational policy, this intervention has led to positive results. Yet, there are challenges that need to be addressed, such as those described in the results of the study herein.

To provide some context, the official Educational Institution Lorenzo Maria Lleras INEM in Monteria has had unsatisfactory results in external tests. The Synthetic Index of Quality of Education (ISCE, for its Spanish acronym) gave a score of 3.85 to the Institution in the area of mathematics in the primary education level in 2015 – a minimum level. The component with greater difficulty is geometric-metric thinking. It must be said that progress has been minimum ever since.

Based on the aforementioned, it was established that teaching geometry is key in the development of geometric-metric thinking (an assessable component in external tests, which should also be preeminent in the educational institution's curriculum). Consequently, it is important to develop pedagogical practices in mathematics, emphasizing on interpretation and comparative analysis, among others.

Accordingly, the need for this research arose with the purpose of studying the didactic phenomenon of reproducibility in a situation involving third-graders in the area of mathematics in elementary education, based on a didactic intervention aimed at teaching curricular content. The teacher is intended to master the mathematical skills of modelling, problem resolution, communication and reasoning, and to emphasize on the field of geometry, generating cross-sectional development in the area of mathematics.

This research aims at facilitating the processes of self-evaluation, action proposals, kick-off and reflection by the educational community's teaching within the area of mathematics. Therefore, it is important to define how reproducibility is connected to other conceptual elements that are inherent to the process, as described by Lezama (2005, p. 358): the phenomenon of reproducibility is also "associated with didactic transposition, since the

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process of adapting a didactic situation to new students is subject to a process of negotiation and adaptation by the person interested in repeating the didactic activity".

It is important to mention that in practice, the impact of the didactic situation was assessed without using the GeoGebra software, and subsequently, using the computing resource, allowing a contrast between the results obtained in each of the cycle's stages.

The implementation of didactic strategies will enable substantial improvement to planning processes to the extent that, based on pedagogical experiences from other scenarios, other learning spaces may be configured for diverse curricular content.

By Way of the State-of-the-art

It is important to mention that literature that references reproducibility as didactic strategy is scarce. For instance, at international level, Lezama (2005) undertook the study: Analysis of Student-Teacher Interactions in the Context of a Work Experience With a Didactic Engineering, which tackled the interaction between teachers and students while working in a stage of the didactic situation corresponding to didactic engineering. The study confirmed significant interaction between the two originated from the application of the strategy.

On the other hand, Cabañas and Cantoral (2009) developed the research: The role of the Notion of Area Conservation in Explaining the Concept of Integrals, a study that described the didactic phenomenon known as reproducibility based on the socio-epistemological notion of research in educational mathematics departing from some of the area's skills such as distributing, comparing and reproducing, measuring, quantifying and preserving. This research used didactic engineering based on its potential for intervention on the teaching system and its capacity to allow assessing research design. Data collection was conducted in the classroom with students in the third semester of a mathematics degree (19-21 years of age), inquiring to which extent they perceived the notion of area conservation and used it in activities that required using graphic and analytical representations connected with regions.

Lastly, a research by Montoya (2005): Reproducibility and Professional Development of Basic Level Teachers. A Case of School Geometry, aimed at reflecting on the reproducibility of learning situations and at analyzing which elements contribute for teacher-created didactic developments to be applied in different scenarios or contexts. This research intended to inquire on the teacher's didactic knowledge based on lesson study methodology; information was collected using documentary analysis, reflection workshops were conducted, as well as interviews to nine teachers that were part of the group, observation of learning situations in 7th grade also took place based on problem resolution by teachers of the focus group.

Theoretical References

The study's analysis categories comprised reproducibility, pedagogical practice, didactic situation and geometry. Regarding the first, Artigue (1986, p. 55) concludes: "reproducibility searches for structures in history and not in histories themselves, and within that structural reproducibility, teachers have an active role to develop".

Didactic engineering (Artigue, 1989) has a double objective: critical intervention of didactic systems, meaning, scientific-based didactic knowledge delimits action; and contingency test, which is the contrast of the produced theoretical proposals. Which is why Douady (1996, p. 241) considers the term didactic engineering to have "a double function in mathematics didactics: as research methodology and as the outcome of teaching and learning situations".

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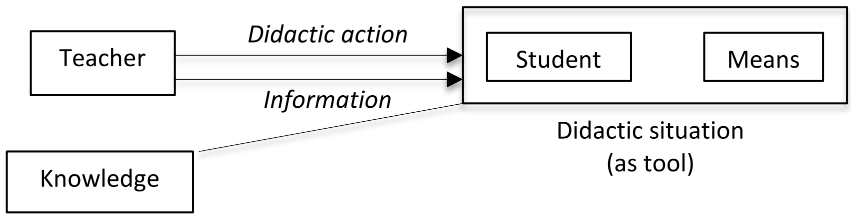
For its part, the didactic situation resembles a system in which students/a group of students, teacher and mathematical knowledge interact. A teacher looks for suitable situations and surroundings, in which he/she organizes an activity plan with the objective of modifying, discovering or crating some knowledge (mathematical concept or idea) in a child (Brousseau, 1997).

Graph 2. Didactic Situation Scheme.



Source: Brousseau (1980). Recherches in Didactique des Máthematiques.

Content's Didactic Knowledge

Regarding the content's didactic knowledge (CDK), Shulman (2005) established that it includes the teacher's connections between the subject's and didactic knowledge. In other words, the importance of mastering didactic and curricular elements of the subject being taught, the capability to present different alternatives when teaching a class and developing the learning-teaching process, all together, provide more meaning to the participants in the educational environment: students, teachers and parents. Therefore, it is necessary to keep all participants in mind, as well as the different scenarios of the educational dynamics, to display the significance of mastering what is being taught and the didactics to teach it as effectively as possible (Shulman, 2005).

Managing the content's didactic knowledge enables the teacher to interact with the subject and didactics, thus driving transposition (transforming the subject's knowledge in ways that generate didactic impact and that adapt to the students' variety in terms of learning pace, skills and background (Chevallierd, 1985)). This is why it is important to know a content's specific didactics, in order to find the right way (from the teacher's understanding of the subject) to accomplish students' motivation and perception, be it through the use of analogies, illustrations, explanations, examples or demonstrations.

Didactic Units and Sequences

Didactic units and sequences constitute key inputs for the tutors' work alongside teachers, within the framework of a sustained didactic accompaniment (Furman, 2012). To articulate the curricular planning and didactic sequences, the first thing is to understand that these models help improve and optimize classroom activities through hierarchical organization of key and secondary concepts presented in sequences, to avoid conceptual leaps in the development of the pedagogical practice. The guiding questions proposed in the sequences allow determining the planning's objective learning, as well as the foundation to design other guiding questions and necessary materials to develop the classes.

Didactic units and sequences go deeper into the CDK of what is being planned, to then develop them with the students and close any arising conceptual gaps. The order of the classes within the sequence, session after session, offers an overall idea of the materials, guiding questions, key ideas, skills and activities needed to correspondingly plan and adapt them depending on the student's needs and interests; it also helps predict difficulties that might happen in the development of the activities, for instance, the lack of a specific material that may be supplied in time.

The use of didactic sequences in teacher's planning implies pedagogical effects that relate to effective teaching and learning. Firstly, the use of didactic sequences translates in time savings for the teacher, since classes need not be planned daily or weekly, consequently, the teacher may allocate this time to other activities that are directly associated with the practice, in order to get better at it. Secondly, it provides a wider vision of the work with students, to the extent that it allows thinking about the work from what has been accomplished in several weeks' worth of classes.

Approach to the Concept of Geometry

Blanco and Berrantes (2003, p. 107) state that "geometry is regarded as a tool that enables the student to understand, describe and interact with the space he/she lives in and interacts with, it may be considered the most intuitive, concrete and conjoined part of mathematics' reality".

Consequently, Vasco (2006, p. 35) ponders on the following concept of geometry: "the Piagetian principle that believes operations are interiorized, reversible and coordinated actions alongside others in a coherent system, leads to the construction of geometric systems, from playing with concrete systems to handling more and more abstract symbolic systems, in order to represent conceptual representations achieved throughout the process".

Which is to say that concrete and symbolic systems constitute the foundation for learning geometric systems. In this process, students develop complexity levels as they construct the conceptualization of the geometric system.

This research intends to explore a new context amid the school: applying the didactic strategy of reproducibility in a scenario in which the teacher develops all the areas of the curriculum and in which mathematics are not usually his/her specialty, given his/her orientation towards elementary education. In that sense, it supposes new challenges and expectations surrounding the implementation of the strategy.

Materials and Methods

The study has a qualitative design projected to account for the phenomenon in question, in which the researcher gets involved with the participants being intervened. It begins with an inductive process, intended to describe the phenomenon to be studied based on the findings and the information compiled. It is simultaneously holistic because the researcher interactively and reflexively integrates the participating subjects to establish formal relationships (Taylos and Bogdan, 1992).

On the other hand, to understand the nature of the existing world, as well as the place and relationships of the individual, a qualitative approach was selected since it allows tackling these matters from a critical thinking point of view as well as direct communication with its analysis units. Qualitative research emphasizes human behavior's subjective aspects of the individual's world, daily experiences, social interactions and meanings given by these experiences. This approach provides several ways of exploring, knowing, understanding and comprehending the existing social phenomena, as proposed by Bonilla (2005, p.84):

> The qualitative method does not work with theoretically derived assumptions; it looks conceptualizes reality based on behavior, knowledge, attitudes and values that touch the behavior of the subjects under study. The qualitative research process systematically explores knowledge and values shared by individuals in certain space and time context.

Also, based on the characteristics of the object of this study, its context and objectives are addressed from the action research perspective, which seeks to transform reality. To which Kemmis and Carr (1980, cited by Bausela, s.f, p. 2) "consider that action research cannot be understood as a transformation process of individual practices, but as a process of social change that is collectively undertaken". To that respect, it is important to highlight the reasons that motivated the study herein, considering its action-participation nature, as follows:

- It is action: the research leads to a structural social change since it drives participants' reflection resulting from an agreed participation, challenged by criticism and proactivity criteria.
- It is participative: to the extent that it drives movement of different groups, not only experts (researchers) have direct influence on action design and implementation, the whole community being intervened strengthens achievement of the study's objectives.

Under the aforementioned conditions, the intervention proposal was planned and developed in three cycles, and each one was structured in four stages: diagnosis and planning, action, observation, and lastly, reflection.

The first cycle, corresponding to the first objective proposed by the research, acknowledges the methodological elements of teaching the geometric system applied by the third-grade teachers at the Educational Institution INEM in Monteria.

This required a characterization of the Institution in terms of the external and internal results of third, fifth, seventh and ninth grades, alongside a reflection and assessment process of pedagogical practices. The results established the main difficulties in the area of mathematics in the third grade. Additionally, it was agreed that the intervention proposal would focus on the aforementioned grade, since it is one of the levels that is subject to the SABER tests, and to intervention from PTA.

Therefore, the researcher (with the support of administrative teachers and teachers at the Institution) presented the proposal. This presentation was followed by a characterization process to identify: teachers' academic training, how they develop their classroom practice, mastery of the content's didactic knowledge and the theoretical basis for their praxis; this part was conducted using a survey and a semi-structured interview.

Afterwards, institutional documentation was reviewed (PEI, area plans, class plans, among others), with the purpose of identifying the level of articulation between what is planned, students' needs, context characteristics and curricular guidelines set by the Ministry of National Education (MEN, for its Spanish acronym).

Finally, a geometry class was observed with the intention of noticing strengths and weaknesses and consequential improvement actions; the information was recorded in a SWOT matrix.

The following is the SWOT matrix with the information compiled through the observation of the pedagogical practice in a geometry class.

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Figure 1: SWOT matrix, information compiled by observing teachers' practice.

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		INTERNAL ANALYSIS	
		STRENGHTS	WEAKNESSES
		1. Use of ITCs in the activities planned to teach geometry	1. Handling geometry learning tools (ruler, protractor, among others)
		2. Appropriate use of the resources in the context to develop the activities	2. Mastery of geometry's basic concepts
		3. Students' interest to learn	3. Lack of specific didactic material (weights, protractors, geometric sets, rulers), chalkboards and compass
		4. The mathematics textbook and notebook	4. Students' production of material
			5. Amount of necessary didactic resources for the students
EXTERNAL ANALYSIS	**OPPORTUNITIES**	**STRENGTHS/WEAKNESSES OBJECTIVES/STRATEGIES**	**WEAKNESSES/OPPORT. OBJECTIVES/STRATEGIES**
	A. Perception of learning new knowledge by students	1A. Organize learning activities for the students taking their needs and expectations into account	1D. Direct the use of instruments (physical or technological) and textbooks regarding learning geometry
	B. Availability of students to ease concept appropriation through practice	1B. Identify resources to appropriate concepts or content	4C. Design instruments for learning geometry
	C. Taking advantage of materials in the context and production of materials	1C. Detail principles and skills that are pertinent for the comprehension of topics	2A. Design didactic strategies to enable the teacher to teach geometry
	D. Good use of time to develop the activities	2D. Plan activities to streamline effective teaching time	
		2B. Define materials that are relevant for planning depending on learning	
	THREATS	**STRENGHTS/THREATS OBJECTIVES/STRATEGIES**	**WEAKNESSES/THREATS OBJECTIVES/STRATEGIES**
	A. Lack of accompaniment by parents	4A. Counsel parents on accompanying their children's learning	1A. Direct parents on the use of instruments regarding learning geometry
	B. Didactic resources necessary to practice and develop the activities	3B. Categorize didactic resources taking themes into account	2A. Explain the principles and skills of the geometry area to parents
	C. Overcrowded classrooms, small space to develop fun activities	4C. Plan students' learning using adequate physical resources	4A. Create didactic material with the help of parents

Source: compiled by the author.

In the second cycle, the study's objective was to develop a didactic situation with the teachers who teach the geometric system that accounted for reproducibility in the Institution's third grade. The didactic situation's planning (addressing class structure) was developed mostly with the study's objectives. A format was applied to follow and include the basic elements, which was also meant to be easy to interpret in class.

Lastly, the third cycle had the objective of building a methodological guide to facilitate reproducibility in a didactic situation with the support of the GeoGebra software. The methodological guide was produced based on a didactic situation that was constructed in the second cycle; this included a variable: the use of the GeoGebra software. The study resorted to this resource given the difficulty to acquire didactic material; in that sense, the software simulated the didactic elements in the development of the classes.

Three strategies were used to structure the guide, which apply to each moment of the class:

- Cognitive Strategy: describes the steps of what is intended, it defines which prior knowledge is required from the students and includes the materials to implement the didactic situation. Students are expected to develop analysis and comprehension skills.
- Technological Strategy: describes the actions that students must develop using the GeoGebra software; it seeks to develop communication, analysis and application, as well as digital skills.
- Didactic Strategy: the student develops the activities proposed by the teacher, working on skills, competences and understanding of concepts.

Results and Discussion

The following results came up based on the evolution of each cycle: in the first cycle, it was established that elementary education teachers develop all of the areas and/or assignments in the Institution's curriculum. Thus, it is important to specify that the absence of a specialist in the area of mathematics in the primary education level hinders the development and deepening needed to comply with the area's components and the MEN's quality references. It was established that aside from their undergraduate studies, to date, they have only received training from the PTA in two of the areas, which include mathematics.

Another important finding is related to the minimum or scarce knowledge of theoretical references in the spheres of pedagogy and didactics to teach mathematics. This is a weakness due to the fact that if the teacher is not competent in the area being taught, good teaching and learning processes are not likely to be encouraged. Likewise, mathematics-teaching criteria, coherent with national references, are not well defined for teachers. They also lack adequate didactic resources. Consequently, this study ascertained the importance of the teacher acquiring skills and abilities to allow him/her to effectively perform. To this respect, learning must be considered an active process in order for the construction of concepts to take place in optimum environments and resources that promote students' interaction (Vasco, 2006).

Moreover, elements were observed in the interview which were also visible in the survey's results and that led to strengthening the hypothesis regarding the difficulties of teachers in their pedagogical practices. For instance, in terms of teaching strategies, it was clear that there were methodological, didactic and time limitations that hinder the participation of all of the students, especially if groups are large. Likewise, students' learning styles and individual characteristics are not taken into account. Orton, Solana and Manzano (2003) emphatically argue that students learn more slowly than teachers think.

In learning situations, teachers lack concrete knowledge of how students learn; it is important to find ways to enhance students' learning and to teach geometry applying several teaching currents (Brousseau, 1998).

In the second cycle, the most significant findings included the fact that academic performance, roughly, is very low in terms of geometry learning, specifically in what involves locating objects with instruments in distance, object and position, and of elaborating conjectures using notions of parallelism and perpendicularity in flat shapes.

Hence, a didactic situation was introduced in this stage to complement the acknowledgement of methodological and didactic elements in class planning. Yet, some resources and elements limitations were observed, preventing a better classroom experience. This led to the implementation of the software to simulate what had been foreseen in class development. It was evident that the teachers lack ITC resources abilities, hence, it was necessary to use external staff (computers and audiovisual media undergraduate students). This is how the GeoGebra software was applied, driving good acceptance levels in students and teachers. It was verified that the concept of reproducibility was embedded in the didactic situation, to the extent that planning was based on experiences from other places and on frequently adopted institutional guidelines to develop teaching processes.

In addition, the learning experience derived from the software allowed students to apply computer resources, which could be applied throughout all areas to further skills and abilities of teachers and students alike.

It was evidenced that the objective, construction and consolidation of a didactic situation applied to geometry took place, which illustrated students' skills and abilities. It also built awareness on teachers about the importance of shifting their classroom practices in terms of curricular guidelines and institutional context.

The didactic situation and the experiences of its implementation resulted in a new challenge: designing a methodological guide as a product and as the foundation of the third cycle. This guide was built from the experience of the implementation of the didactic situation in the third grade, which led to didactic actions that favored the reproducibility strategy. This technological resource had a positive impact on classroom practices in the area of mathematics, particularly in teaching geometrical thinking. The methodology is recorded in a booklet, describing what the teacher must do in each didactic situation using the GeoGebra software in order to favor reproducibility.

In terms of the actions developed in the study, the objective was met because the strategies applied by teachers in their pedagogical practice were established. This permitted a diagnosis that was used as input for the researcher and the Educational Institution as well, which derived in the generation of intervention or improvement plans to strengthen students' learning and teachers' classroom practices.

Conclusions

This study is a contribution to the improvement of pedagogical practices based on the reproducibility of a didactic situation. This may be materialized in didactic actions consolidated as strategic tools in the progress of the area of mathematics in local, regional or national educational institutions.

The researcher set parameters to frame the study, however, the context's characteristics, subjects involved and processes applied led to situations and elements such as using the GeoGebra software and the involvement of undergraduate students, which imposed new challenges and actions on the study, the results obtained were satisfactory.

The curricular program for teaching geometry must run in parallel to other contents in the area of mathematics to avoid geometric thinking to become a sort of filling (in many cases, as a result of the limited time in the year's last term). This is why it was important to reorganize the plan of the area of mathematics, with geometry becoming a relevant discipline of the curriculum.

Applicability of the didactic situation and the GeoGebra software helped improve the scenario of geometry teaching. The acceptance of teachers and students was clear throughout the experimentation of the didactic situation, consequently, work dynamics, student participation and didactic management of curricular content significantly improved.

The aforementioned indicates that the phenomenon of reproducibility strengthens classroom practices in the area of mathematics, thus enhancing students' academic performance. This fact builds a background of didactic knowledge of the area's content, unblocking the possibility to consolidate new pedagogical and didactic strategies.

Teachers acknowledged the importance of structuring area plans and class planning as an opportunity to improve their pedagogical practices to benefit the student community. This drove collective awareness in terms of the importance of these processes and of building a better scenario for school development, from a pedagogical and didactic perspective.

Recommendations

For teritorial entities and/or educational institutions: training teachers in didactic situation design and in the use of the GeoGebra software, in order to produce methodological guides to apply in the mathematics class. This will introduce interactive material that is totally free and accessible for students, thus implementing ITCs in the classrooms as pertinent tools for students' learning (tapping into their love for technology).

For teachers: understanding planning is critical for the praxis, reflecting on and including didactic situations that are interesting for students, encouraging meaningful learning and empowering students to become active players in learning from a context-based experience.

Likewise, implementing the use of the methodological guide in the area plan for other grades, allowing the teacher to get better at the didactic situation and to apply it in other contexts using the GeoGebra software (since the tool provides several applications to work with other topics and levels).

To the Educational Institution: establishing agreements with regional universities to undertake knowledge exchange between undergraduate students and the Institution's teachers. It is important for interning students to instruct teachers in new technologies, instruments' design and meaningful experiences that permeate to their classroom practices.

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