

## **Helping interventions aimed at students “in difficulty” in Mathematics. Some tensions in a Cooperative Engineering device.**

*Andrea NOVEMBRE*  
Universidad Nacional de Hurlingham, Argentina  
*Claudia BROITMAN*  
Universidad Nacional de La Plata, Argentina

### **Abstract:**

In this paper we share some excerpts from a study on types of helping interventions aimed at students "in difficulty" in Mathematics.

We put in dialogue the mathematical learning of students and the didactic activity of teachers based on helping situations. To do so, we developed a Cooperative Engineering through which we designed, implemented, and analysed a didactic unit on a Geometry content for a first year of secondary school. We will focus on certain tensions in the work between researchers and teachers that arose from the interpretation of classroom phenomena.

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### **Résumé :**

Dans cet article, nous partageons quelques extraits d'une étude sur les types d'aide destinés aux élèves "en difficulté" en mathématiques.

Nous mettons en dialogue l'apprentissage mathématique des élèves et l'activité didactique des enseignants sur la base des situations d'aide. Pour ce faire, nous développons une Ingénierie Coopérative à travers laquelle nous concevons, mettons en œuvre et analysons une unité didactique sur un thème particulier du curriculum (Sensevy, 2018). Nous nous focaliserons sur deux enjeux spécifiques de l'ingénierie développée : certaines tensions dans le travail entre chercheurs et enseignants qui sont nées de différences dans l'interprétation des phénomènes de classe.

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**Key-words:** Cooperative Engineering – Mathematics teaching – Helping interventions – Students in difficulty.

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**Mots clés :** Ingénierie coopérative - Enseignement des mathématiques - Interventions d'aide - Élèves en difficulté.

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## **1. Introduction and theoretical framework of the thesis that originated this study.**

In this paper we share some excerpts from a study on types of help aimed at students "in difficulty" in Mathematics. The problem is framed in the recognition of a didactic problem of teaching practices. Faced with the students' lack of strategies, it is often the teachers who find themselves "in teaching difficulty". When the various interventions they develop prove insufficient to make students' knowledge progress, some choose to help students by offering them algorithmic procedures or by suggesting that they imitate certain ways of solving problems in a process of seeking immediate success (Peltier Barbier, 2006), even among teachers whose practices are constructivist. Moreover, teaching interventions are often affected by certain constraints to which teachers are subject, such as the need to make progress in didactic time (Chevallard, 1997; Mercier, 1993; Sensevy, 1996).

In our research, we problematise the meaning of being "in difficulty" based on contributions from different authors (among others, Perrin-Glorian, 1993; Brousseau, 1999; Toullec-Théry, 2006; Sensevy, 1998) who agree in pointing out the risk of assigning characteristics to pupils that, in reality, result from the didactic system, and we include the idea of "transitory difficulty". We also appeal to the concept of "help" on account of various contributions (among others, Toullec-Théry, 2006; Block, Ramírez and Reséndiz, 2015) that consider that the didactic interventions required to promote transformations in knowledge and in the relationship with mathematical knowledge involve encouraging certain types of mathematical practices and a particular epistemic position. Butlen (1996) asks "how to help students solve a complex problem by providing limited aids, without reducing the task to a simple execution of rules and without limiting the mathematical meaning of the situation" (p.202). For many pupils, and more so for "weak" students, doing mathematics becomes almost an act of guessing, of discovering a prefixed and unique strategy. For them, finding the way to solve a problem often responds to external clues, to "key words" void of mathematical reasons (Novembre, 2011). Perrin Glorian (1993) has identified a phenomenon whereby some students do not seem to have what she calls a "learning project". Thus, they retain the activity performed but not the new knowledge. She proposes types of didactic interventions and forms of classroom management that help students learn to construct a position involving a "learning project".

This idea is quite close to Charlot's concept of the construction of the "epistemic self"; in both cases the student is limited to the experience but does not project the activities carried out in terms of learning (Broitman, 2023). Charlot (2006) develops the notion of "relation to knowledge" to analyse academic failure from a perspective that includes the subjective position with respect to knowledge.

While we have named on the one hand the students "in difficulty", and on the other hand the "helping" interventions of the teacher, according to Toullec-Théry (2006) they are two terms that "attract and associate with one another". A difficulty occurring at any of the poles of the system (teacher, student, knowledge) needs to be considered as a difficulty of the didactic system and requires the inclusion of broader institutional dimensions in order to understand and transform classroom phenomena.

In Sensevy's (2007) Joint Action Theory in Didactics, classroom practices are conceived as joint epistemic acts that can only be described through an analysis that simultaneously contemplates the transformations and interactions between students, teachers, and knowledge, i.e., the didactic game. The student, like the teacher, is subject to tensions: he/she knows that he/she is expected to act of his/her own accord. The teacher's interventions must not allow him/her to obtain the correct answer without calling on the necessary knowledge. This tension is closely related to what the teacher "says or does not say", i.e., to the reticence-expression dialectic. In previous works we have mentioned that the teacher's words and silences can collaborate with the student in the reorganisation of his or her action (Novembre and Broitman, 2021). In this section we have mentioned the main theoretical references of the thesis that frames this presentation, although for reasons of space we do not appeal to all of them in the episode under analysis.

## **2. Methodological decisions and framework of the research**

We developed a Cooperative Engineering (Sensevy, 2013) between researchers and teacher through which we designed, implemented, and analysed a didactic unit (approximately 12 meetings between researcher and teacher and 8 classes with students). We anticipated different interventions to help a "common" group of first year secondary school students. We studied the transformation of the knowledge and the relationship with mathematics of students in difficulty as a result of the helping interventions received, as well as the transformation of

the teachers' knowledge about their practice when anticipating, providing and analysing helping interventions, whether anticipated or spontaneous. From this theoretical and methodological perspective, we will focus on certain tensions in the work between researchers and teachers.

The decisions about the choice of the course, the time of the year and the content were not neutral. We selected a group of first year secondary school students because they are in a situation of building a new relationship with school and developing new mathematical practices. As it is the beginning of the year, the teacher does not yet know her students, so she will not have certain preconceptions about their academic performance. In this way, it will allow us - at least initially - to observe the helping interventions devoid of certain assumptions about the addressee.

The content was agreed with the teacher. Given the differences in available knowledge that students are expected to have at the beginning of their secondary schooling after two years of the pandemic, we decided to start with a first unit on Geometry, based on the idea that this is a content with little presence in primary school and on the assumption that virtuality made it more difficult to deal with. We thus anticipated that most students would find themselves in similar situations when dealing with the topic.

It is important to clarify that the researcher was the mathematics coordinator at the institution where the study was carried out. Due to the roles they both played and the important history of shared work, the researcher's interventions in the classes were very common. In the Methodological Reflections section, we will return to this issue when analysing certain features of the Cooperative Engineering developed.

### **3. Analysis of an episode**

In a joint work meeting, the researcher told the teacher that she was concerned about the lack of progress in the didactic time of the previous class. We clarify that this issue had been a subject of reflection between the two of them in the framework of their shared institutional work for some time, given that in most of her courses there was a certain dilation of the students' discussion and debate times, and a certain difficulty in promoting progress towards the processes of systematisation and institutionalisation.

The authors of this publication, in our roles as teacher trainers and in our work in educational institutions accompanying the teaching, have been able to identify a similar phenomenon. In the first contacts with a constructivist perspective that seeks to promote a

certain amount of autonomous intellectual work among students, there is often a kind of "fascination" with the possibility for children and young people to produce their own ideas, to invent strategies for solving problems or to participate in passionate dialogues about the validity of certain ideas. The phenomenon we are referring to is a certain tendency at these times to place more emphasis on the processes of devolution - abandoning practices of direct communication of knowledge - which goes hand in hand with a certain postponement of the advancement of didactic time, i.e., a delay or blurring of the processes of institutionalisation. The rupture with the more classical approach to teaching sometimes generates a certain abandonment or postponement of the processes of recognition and reorganisation of knowledge.

We have found that a similar phenomenon also occurs in some instances of collaborative work between researchers and teachers studying the functioning of a teaching proposal. In some ways, research times - which are slower - sometimes put pressure on teaching times, delaying classes, not because of the students' needs, but because of the researchers' need to document in detail the knowledge produced by the students.

In this study, however, the tensions around "time" take on some particular characteristics. The students had shown difficulties in constructing angles using a protractor, particularly in selecting which one corresponded to a given magnitude - whether that of the given angle or that of its supplement<sup>1</sup> -, so the teacher decided to help them one by one. In this situation, she narrates the episode as follows: "Well, this one, [problem] 1b, took the whole hour, because they don't know how to use a protractor, and I had to make personalised interventions: hold it [the protractor], show them that there were two options [clockwise and counterclockwise]". It is possible to analyse from her comments some of the constraints to which the teacher is subjected to as an educator: her perception that the students "don't know what they should know", the feeling of "wasted time" given the students' difficulties, and her interest to try to help each one personally.

In response to her concern about what had happened in the first class, the researcher shares with the teacher the hypothesis that the problem was not strictly in the handling of the instrument, but in the fact that the students may not have had control mechanisms to know whether the triangle constructed was pertinent for the data of the problem. She raises the didactic conjecture that if students could anticipate what shape a triangle is going to have

<sup>1</sup> The protractors most commonly used in our country are the 180° ones, which can be used to measure angles in a clockwise or counterclockwise direction. For example, the same point can be used to construct a 60° angle and a 120° angle.

when two of its angles are known, then they would know if they were using the protractor effectively. This intervention by the researcher generates a shift from the intention of mastering the instrument and the techniques to an analysis of how anticipation and subsequent contrasts can be tools for control. We interpret, at this point, that the change of perspective is linked to the search for the technique to leave its priority role as "object of study" to become a "tool or instrument" (Douady, 1994).

In the exchange, both teacher and researcher considered that anticipating the shape of the triangle would help the students. They agreed on the need to do so and planned a collective work aimed at making explicit how to anticipate the shape of the triangle. Some - non- consecutive - comments of the teacher during the planning phase - shared role of the engineer - show the agreement between the two:

*T: OK, I'll do an introduction, like a reminder... or an anticipation.*

*T: I was going to write down a reminder about how to mark [the angle] and then I said no, no, no, no, what we want to do is to anticipate the shape of the angles according to their measure.*

*T: And also advise them, when they draw them [the triangles], to compare with that anticipation.*

We would like to point out that in her second comment, the teacher begins by saying that the focus was going to be on the construction of the angle, and then corrects herself and comes back to the agreement. We think it is possible that there was some internal debate on her part between the two options, even though she made it explicit that the researcher's proposal seemed correct to her.

When the time came for the class, two days after the meeting, the teacher proposed the planned problem, which called for the collective construction of a triangle ABC, in which  $|\widehat{CAB}| = 60^\circ$ ,  $|\widehat{ABC}| = 100^\circ$ ,  $|\widehat{BCA}| = 20^\circ$ . She begins by recalling - in interaction with the students - certain knowledge necessary to carry out the construction and reminds them of nomenclature conventions. However, when the time comes to construct the angles, she returns to the strategy she had shared with the students in the previous class, i.e., the one that emphasises on deciding whether the direction of the angle is clockwise or counterclockwise, without even mentioning any anticipation.

The collective evocation work began with a reflective exchange about the data, the possibility of constructing the triangle and ways of naming its elements. Facundo (a student who usually approaches problems with an attitude of oral search and exploration, but who then has difficulties in the solution of individual tasks and in the written communication of his productions, pointed out that it was necessary "that it fits on the sheet", as a practical - and not mathematical - question when it came to tracing the first segment.

When the time came to construct the angles, the same difficulty - and the same teacher intervention - as in the previous class was raised again for the whole class. Some students understood how to determine the correct angle and participated actively in the discussion, until one pupil said that she could not understand how to do it. The teacher stops at this question and repeats her interventions and guidance on the use of the protractor. Seeing that the difficulties persisted and based on the analysis made between the researcher and the teacher, the researcher - through a rhetorical question - asked to intervene in the class:

I: *Can I say something?*

*Let's see, one thing, look at this: if we forget a little bit about the construction you're doing and try to...*

Facundo: *I can tell if it's acute or obtuse...*

Facundo's quick response - he even interrupts the researcher without allowing her to finish her intervention - shows his personal understanding of anticipation without needing to actually construct the angle. We note how this same pupil - about whom we have mentioned his significant difficulties in the written processes of resolution - has more than pertinent interventions in oral exchanges. This comment merely seeks to emphasise that this is not a student "with difficulties" but one who faces difficulties in a certain type of mathematical activity - and not in others - like all students.

Returning to the class, the researcher takes up Facundo's intervention and continues with her interrupted explanation of the sense of the process of anticipation. During this intervention she recovers geometric relations already worked on in previous classes<sup>2</sup> and introduces - without making it explicit - a new geometric strategy: constructing a figure of analysis. In this way, the researcher continues to show the students an important tool of geometric work, which both had decided to present, since it was not yet available to them. The direct presentation of this practice was decided as - at least in our experience - it is not usually constructed

<sup>2</sup> In previous classes they had worked on triangle constructions, triangular inequality, sum of interior angles, among other issues.

autonomously by the learners as they are solving problems.

I: *There you go (validating what Facundo said), I think about it beforehand to see what shape it's going to be. Can we think about this for a minute? Before drawing it, because that will help us later to know if the drawing we made is correct or not. So, we have to draw a triangle. I'm going to do it by hand, because this is just a sketch, okay? I know that the angle centred at B has to measure 100°. 100° is what? An angle of what type?*

Various: *Obtuse.*

I: *So, in B, we know that the angle is obtuse. I'm doing this by eye (while drawing an obtuse angle on the board). Do you agree?*

Various: *Yes.*

I: *The angle centred at A, is an angle of what type?*

Various: *Acute.*

I: *Then it has to be less than 90 degrees. So, at A, I'm drawing an acute angle... This one is 60°, this one is 100° (while drawing, and it can be seen that there is only one possibility for the third angle), and this one is determined, isn't it? Because there is no other option than that one, which is 20°. This is the shape it has to have. That's where we have to get to (referring to the fact that the triangle to be built will have a shape similar to that anticipated triangle). Knowing the shape allows you to then choose on which side you are going to measure the angle when you place the protractor. So, if you think of this angle of 60°, this is for you, look (addressing a student who had said she didn't know which side to build the angle for), you should think of it as two straight lines that are opening up. The question you have to ask yourself is how these lines open up, if they open up like this, or if they open up from here to there (making hand gestures). If you take this side as a base, the first angle opens up like this, is that right? So if it opens up like this, the 0 will be here, and as it opens up, it will measure more and more. So when Romina<sup>3</sup> put the 0 here, it was because she considered that the angle was opening up like this. Is that OK? If we look at the angle in B, it opens up the other way round, it opens up from here to there, until it reaches 100. If we put the 0 here in B, and here is the 0, it will open up this way until it reaches 100. And if you make a mistake (when constructing the angle), and you look at the wrong one, you won't get this shape, OK?*

Thus, the researcher - as agreed with the teacher - communicates a way of anticipating what the triangle will look like by focusing on the "aspect" of each of the angles to be constructed in terms of whether they are acute or obtuse, comparing each one with a right angle in terms of whether "it is more or less closed", i.e., anticipating its shape. Although we reproduce only what the researcher says - for reasons of space -, it should be noted that the students, during the explanation, participate by nodding, drawing on their folders, with expressions such as "ah, now I understand" or "sure, you should sketch it before you draw it to make sure it looks right".

This single intervention by the researcher is continued by the teacher, who immediately resumes the function of anticipation, and showing the possibility of recovering what had been

<sup>3</sup> Romina is a fictitious name for the teacher.

discussed in the planning and analysis phase of the difficulties that had arisen in the previous class. The class continues in the hands - exclusively - of the teacher, who abandons the emphasis on the use of the protractor and redirects the students' work again and again towards the power of anticipating what the triangle will be like prior to its actual construction, and how this anticipation becomes a tool for controlling the use of the protractor and the pertinence of the triangle already constructed.

After the class, the teacher was distressed and explained that she had not understood what the researcher had proposed as a collective help, despite the fact that her expressions reflected an agreement on the convenience of working on anticipation. We doubt that it was a question of "understanding", given that the teacher, in response to the researcher's intervention with the students, immediately reoriented the course of the class. We believe that the possibility of continuing the class after an external intervention could be the result of the confidence built up between them.

In terms of cooperative engineering, we think that the symmetry built, the joint analyses carried out and, fundamentally, the trust between the two allowed a move towards a new strategy of the students and the consequent resolution of a previous obstacle they had faced. The actions of both allowed the work to be reoriented towards anticipation.

Thus, faced with the difficulty that many students had, a collective help intervention was planned and proved fertile, as evidenced by the fact that almost all the students were able, for the following problems, to use diagrams as figures of analysis when they considered it appropriate. Some of them even reflected that they did not need to anticipate if the problem did not include the measurement of an angle. We interpret this new knowledge as enriching their geometric practices and their ways of doing mathematics.

We highlight the power of the subsequent joint analysis process between researcher and teacher on the tensions raised during the class and how these reflections allow the participants to broaden their knowledge about their practice. The exchange produced in the course of which a joint retrospective look is taken at the decisions made *a priori* and in the class are just examples of the conditions necessary for the co-construction of a "work" (Sensevy, 2019). In this process, it is possible to identify the search for symmetry in the framework of the interactions of this cooperative engineering.

## 4. Methodological reflections

We will return here to some of the tensions that unfold during the course of the work on the basis of Cooperative Engineering.

We could interpret that the teacher "did not comply" with what was agreed, which would lead the analysis to think, as was done in classical didactic engineering back in the 1980s, that the teacher "deviated" from the sequence elaborated by the researcher. However, in the framework of Cooperative Engineering, where researchers and teachers share both the task of engineer and that of practitioner - contrary to the hierarchical division of tasks where some plan and others implement - we do not interpret this phenomenon in terms of the distance between what is planned and its implementation, but in terms of the tensions inherent in teaching, where the decisions that are made involve both "reading" what is happening with the students and considering the anticipations that have already been made. Thus, the teacher is once again concerned during the class, in the same way as in the previous class, about a certain difficulty presented by the students in the face of the actual construction, and "forgets" the agreement that had arisen from the joint analysis prior to the class. Nor is the researcher's intervention read as an interruption, as if the class "belonged to the teacher", but rather the researcher and teacher also share responsibility for the teaching in a cooperative engineering process. The collective - in this case consisting of only two people - is jointly responsible for the whole process of planning, analysis, implementation in a permanent search for and support of avoiding hierarchies and building symmetries. Neither the teacher "deviates", nor the researcher "intrudes". We even confess that at some point we doubted how to interpret the researcher's participation and whether it had been relevant, but our analysis allowed us to reflect again on the shared roles both during the "engineer's position" and in the "practitioner's position" (Sensevy, 2019).

Some readers might suppose - just as we ourselves have wondered - whether the teacher has shown acceptance during the planning as an effect of a didactic contract<sup>4</sup>, beyond the fact that it is not a didactic relationship. In other words, did the teacher passively accept the researcher's proposal to offer the students the geometrical practice of constructing a figure of analysis as an anticipatory strategy, without agreeing with or understanding it? We ruled out

<sup>4</sup> Brousseau (1999) introduces the concept of didactic contract to analyse those interactions in which the teacher manifests his or her expectations to the learners through certain habits that allow them to identify the expected response without resorting to a process of elaboration of their own. Correct student responses produced through such interactions can be interpreted as didactic contract effects.

this interpretation on the basis of the history of joint production between the two and the teacher's immediate reaction during the class itself (recovering the anticipatory practice in all the following problems) and at the end of the class (commenting autonomously and in a climate of complicity that she now realised that perhaps she had not fully understood how to lead the class towards the anticipatory practice).

In addition to sharing with our readers our approaches to Cooperative Engineering and the doubts that arose during a phase of analysis that followed the one shared with the teacher, we also share a conjecture. Perhaps the teacher, whose practices are undoubtedly constructivist and aimed at getting the class to function as a group of mathematicians producing their knowledge in interaction with the problems they solve and debating about them democratically, did not feel entirely comfortable with having to "teach directly" a type of practice that did not stem from the autonomous and genuine work of the students. We link this interpretation to the fascination that occurs in teacher training spaces to which we referred earlier.

Finally, we would also like to share some methodological questions. We have mentioned different instances shared between researcher and teacher in the framework of Cooperative Engineering linked to the position of the engineer and the position of the practitioner. However, and not without contradictions, we have identified a certain tension at this stage (for example, the teacher is not a co-author of this work, nor will she be a co-author of the thesis in progress). A first possible interpretation would be that the working conditions of institutional teacher work in Argentina - which do not facilitate long processes of shared analysis - and the conditions of scientific production - which do not allow theses to be conceived as collective works - make us think that our research could not be, strictly speaking, a Cooperative

Engineering, in spite of the intention.

Another possible interpretation is that this current phase - already distant in time from its development and without the active presence of the teacher in the analysis and writing - would be that the Cooperative Engineering ended when the time and the possibility of shared analysis between teacher and researcher began to diminish. Thus, this new moment of production of the doctoral thesis - in which the present work is housed - takes Cooperative Engineering as an object of study by the authors of this paper.

A third hypothesis is that in the current phase we would be developing a subsequent work to that carried out jointly with the teacher, and which is characterised by the process of writing the doctoral thesis that frames this work. Although we share our current analyses with the teacher, the timescale for writing a thesis, at some points, seems to show us certain practical

limits in the search for symmetry and cooperation. Perhaps we could think that in this case there are different "levels of cooperation" between phases in which it functions as a collective, and a last phase in which, without losing the link with the professor, cooperation is blurred.

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