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Co-operative Learning in the Teaching of Mathematics in Secondary Education

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ABSTRACT From an idea of diversity as source of richness for the educational and social development of students and a constructivist conception of learning, we have designed and experimented a proposal of classroom intervention for the area of Mathematics in one of the Compulsory Secondary Education cycles in Spain (14/16 years); this proposal is based on the principles of co-operative learning. Coinciding with the conclusions of other researches about the improvement of academic performance, we also conclude that the factors that influence its improvement are the structuring of the task in a 'tutoring' situation and the role that the teacher plays in the group. Thus, we have shown that co-operative learning is an alternative to answer the socialization, motivation and academic performance problems, and we have verified that co-operative strategies can be an efficient tool, among others, to improve the class climate.

Introduction

The ability to co-operate and work collaboratively has become one of the most important competences for citizens to reach in the current society of knowledge and information. However, in some educational contexts, students' interactions in class are not considered desirable even today. Thus, in highly individualistic and competitive environments, to ask a classmate for help often has a negative meaning, considering it as a sign of dependence or weakness.

On the other hand, we have analyzed a large amount of research that concludes that if we organize learning activities in a co-operative way, that is to say, when learning tasks are structured so that students collaborate, there are more positive effects in the co-existence, motivation and school

performance than when they are structured in an individual or competitive way (Echeita & Martin, 1990).

Anyway, we must point out that, the label of co-operative methodology hides a certain diversity in the types of interaction among equals. 'Co-operative Learning' comprises a set of techniques that can be used at any academic level, and in most areas and subjects. For instance, Damon & Phelps (1989) identify three approaches that consider the relationship among equals as a reference point:

- In the field of tutoring among equals, a student who is considered an expert in a given content teaches others that present a lower level of competence.
- In the field of collaboration among equals, two or more students with a similar level of competence work together in the development and solution of a task.
- In the field of co-operative learning, we start by organising the class in small heterogeneous groups, of two to six members, where students work together in a co-operative way to solve mainly academic tasks. The group's objectives are only attained if the group's members collaborate in their fulfilment and, at the same time, each student reaches his/her objective only if the group does so.

In general, co-operative learning is understood as those situations in which the class is organized in mixed and heterogeneous groups, which work with the same goal to solve the assigned academic tasks in a co-operative way. On the other hand, Slavin (1985), Johnson & Johnson (1990b) or Ovejero (1990) have developed researches that agree that co-operative structures are more favourable than individual or competitive ones in different aspects of the learning process because they provide a greater school performance, a higher quality of reasoning, more intrinsic motivation, more interpersonal attraction, more self-confidence and better solutions to inter-group conflicts. We have wanted to check the effects and benefits that structuring tasks in a co-operative way offers in some of the problems that concern and obstruct the teaching task (especially Secondary Education teachers) (INCE, 1997). Anyway, we know that it is not enough to know and practice the possibilities offered by any novel way of working in class if, at the same time, we do not question the conventional and routine practices of teachers, such as the inertias of the educational system as a whole (Rué, 1998).

Mathematics and Co-operative Learning: a revision of literature

Many of the researches developed about co-operative learning have been focused on determining the effects that these methodological strategies have in specific areas of the curriculum. Thus, they have been developed and applied in different subjects, such as Language and Literature, Geography,

Natural Sciences, Biology, etc. However, it is in the field of Mathematics where co-operative learning has been used more, perhaps due to the high level of failure that this subject involves in almost all the countries in the world.

The same reason made us develop the research: the area of Mathematics and Compulsory Secondary Education students, where the problems of co-occurrence, motivation and performance are sharpened. Nowadays, such problems increase not only in Spanish classrooms, but also in those of the majority of Western countries.

Johnson & Johnson (1990a) point out, after revising 17 researches about Mathematics learning under co-operative methods, that students who work systematically with these techniques show improvement in:

- the use of reasoning strategies;
- the ability to generate new ideas;
- the appropriate solution to problems;
- the ability to transfer what is learnt in the group to the individual solution of problems.

In addition, the same authors underline the convenience of using techniques of co-operative learning in Mathematics due to, at least, the following reasons:

- Co-operation involves a greater performance than competitiveness and individualization.
- Mathematical processes require an active learning process that emerges easily in students' discussions. The traditional way of teaching Mathematics has been based on the assumption that students are passive subjects that store what they learn as the result of repeated practice and reinforcement (Keyser, 2000).
- The solution of mathematical problems involves an interpersonal work and most students feel more comfortable clarifying their thought in small groups, rather than in the discussions of the whole class. Discussing problems with classmates helps students to understand how to solve them in an adequate way.
- The groups that are co-operatively structured involve a greater intellectual exchange that is essentially needed in the process of teaching and learning Mathematics.
- Within co-operative groups, students receive a supporting interaction that allows them to increase confidence in their own individual ability for Mathematics.
- In co-operative learning situations, students like Mathematics more and they are more intrinsically motivated to continue to learn it.

From this perspective, Robertson et al (1994) point out that students provide a forum in which they can ask, discuss, rectify, receive new ideas and summarize acknowledgements. Thus, it constitutes a suitable environment for all students to be successful and progress since they are stimulated by the different contributions that emerge in the bosom of co-operation. Besides, it becomes an essential social mechanism of support in order to learn mathematics.

Co-operative Learning Methods in the Mathematics Area

The structure of tasks in Mathematics allows a lesser probability of modification than in any other subject. This fact makes impossible the use of certain techniques and, due to this, specific methods of co-operative learning for Mathematics have been designed. Among the most significant we can find: 'Small group learning and teaching in Mathematics' (Davidson, 1980), the TAI (Slavin, 1985) and the MACIM (Gonzalez-Herrero & Martinez Artero, 1997).

In order to check the efficiency of co-operative learning methods in Mathematics learning, these methods have been compared to the traditional classes in big groups. These comparisons have been established from several perspectives, though basically referring to the following aspects: school performance or social relationships among students.

Serrano & Calvo (1994) point out that in the researches that made these comparisons related to school performance in Mathematics, in general, we cannot observe significant differences from the statistical point of view between both teaching and learning models. Nevertheless, when they occurred, they always favoured those that had used procedures of co-operative learning.

Among the methods that have been especially elaborated for Mathematics learning, the TAI is the one in which the comparisons, according to Slavin et al (1984) acquire better results. However, the MACIM has also been shown equally consistent and its results have also demonstrated that it is able to produce a significant improvement, from the statistical point of view, in the students' performance in Secondary Education (Serrano & Calvo, 1994).

Peterson et al, (1981) conclude that students with a high level in Mathematics produce more when they work co-operatively than when they do it in the traditional way.

Bond & Titus (1983) establish, from 241 studies, the importance of co-operative learning methods as promoters of social relationships in class and, in short, in Mathematics. In this sense, Slavin et al (1984) point out that the students that were integrated with some kind of shortage, as a consequence of a mental, physical or psychic deficiency, presented fewer problems of integration and behaviour when they studied Mathematics in small groups, instead of following the traditional way.

Our Proposal: learning Mathematics in co-operative teams (AMEC)

Co-operative learning, by itself, does not prove unquestionable benefits. According to Rué (1998), it is necessary to incorporate in classrooms, in the design of the social situations, as well as in the profile of the work to do, those factors that increase an interaction of norms and quality that will favour international co-operation and the group's perseverance to attain the proposed objectives.

Thus, the AMEC (Mathematics Learning in Co-operative Teams), method that we propose, is based on three fundamental pillars:

- conception of diversity as a source of richness for the educational and social development of students;
- constructive conception in which the teaching and learning processes are configured as promoters of the regulation and self-regulation of these processes;
- principle of interactivity by means of co-operative learning.

From this perspective, our educational intervention starts from a conception of constructive learning that:

- starts from the level of development of students;
- ensures the building of significant learning;
- makes possible that students develop significant learning by themselves;
- modifies the knowledge structures that students have;
- favours an intense activity–interactivity of the student (Niemi, 2002).

Our proposal emerges from the adaptation to our context of certain conclusions made by representative authors in the topic 'Co-operative Learning', as well as of a series of principles and techniques to which we recognize an unquestionable influence:

- The 'Small Group Learning and Teaching in Mathematics', method created by Davidson in 1980 for its specific application in Mathematics classes.
- TAI (Team Assisted Individuation), technique invented by Slavin in 1984 preferably for teaching Mathematics to students from 3rd to 5th grade. It combines co-operative learning with individual training.
- MACIM (Method of Co-operative-Individualist Learning for Mathematics Teaching) It was created by Gonzalez-Herrero & Martinez Artero in 1997 for its specific application in the area of Mathematics in Secondary Education.

We should add to them the experience stored by all the members of the research team during several years testing different techniques of co-

operative learning in class, as well as the experience of other colleagues in different subjects, most of them in Mathematics.

Basic Principles

The main principles that rule the experience would be:

- ordinary distribution of students in heterogeneous group-class;
- the working teams will also be heterogeneous;
- co-operation among the members of each group;
- equality of opportunity;
- protagonism of students;
- individual and work group evaluation.

Structure of the Task

There is little doubt that one of the most decisive aspects in co-operative work is the co-operative design of tasks. Thus, as Rué (1998) points out, a teacher's imagination is important when developing working situations different from the habitual ones that are so typical of the individualistic work.

The creation of groups will be made by teachers having in mind both students' performance in Mathematics, as well as the interpersonal relationships among students.

From this perspective, the groups that are formed must have the following characteristics:

- to be formed by three members that will alternate the work in a big group, in a team and individual work during the teaching and learning process;
- to be heterogeneous regarding the level of performance of members;
- the team must have certain group cohesion that favours and promotes collaboration and co-operation when developing the task;
- the spatial distribution must be coherent with the co-operative and team work structure, and must remain stable at least during one trimester.

Teacher's Role

The teacher's role in our methodological proposal is fundamental as it contributes to the class climate and allows people to develop themselves in a working environment of confidence, participation, dialogue, co-operation and mutual respect. The teacher must be an active participant in the process of building knowledge on the student's side.

On the other hand, the teacher must assume the role of observer, mediator, adviser and/or tutor that guides, supports and solves problems, at the same time promoting a series of basic norms that must continue

during the group's interaction. From these assumptions, the teacher's functions are basically the following:

- to promote the students' interest in the new learning contents;
- to value the level of previous knowledge of students;
- to prepare the didactic units expounding their most relevant contents to the whole class;
- to elaborate and/or select, from the explained topic, the material that students will work on in groups – he/she will only intervene if the difficulty cannot be overcome among the members of the group and, as a last resort, by none of the group's members and his help is therefore asked for;
- to make sure that the relationship among equals is the adequate one;
- to organize the student's self-evaluation and co-operative teams providing them with information about the mistakes that are produced in their work;
- to evaluate the work that students perform each day by means of the valuation of their homework, class notes or interventions in class, and with respect to the team's functioning and the quality of their interactions.

Basic Norms of Interactions

Individual co-operation does not have its origin in the verbal instructions of the teacher, but it is an interaction modality in the activity that is configured by the characteristics of the task (Ruè, 1991).

In any case, before starting this teaching and learning method, we have developed in several sessions a 'Programme of Co-operation of Social Abilities' for students with the aim of achieving quality interactions among the members of each co-operative team and that students learn:

- to be individually responsible for their own work and behaviour within each group;
- to co-operate among the team's members, either providing or asking for help when required, and ensuring that all the team's members understand the solutions to problems and issues before going forward;
- to listen to all team mates trying to take profit from their contributions and trying to ensure that that all the team's members participate.

Evaluation Structure

The evaluation structure in our methodological proposal constitutes a fundamental element in order to achieve the fulfilment of the basic principles of co-operative learning. Thus, the mark that each student finally obtains is the product of a series of factors in which the following elements

play a role: the average obtained by each team, the self-evaluation of each student and the self-evaluation of the team, plus the valuation that the teacher makes about the co-operative abilities developed by each student.

Didactic Material

Students will dispose of the material they have to work through every didactic unit. This material will be formed by the following elements:

- the material named 'Programme of social abilities of co-operation' if it is the first time that this methodology is carried out with a group of students;
- textbooks and/or didactic unit made by the teacher;
- guides of individual and small group self-evaluation, either initial or final, where the didactic objectives of the unit are reflected;
- model of 'didactic contract';
- templates of individual and small group self-evaluation referred to the quality of interactions and work performed through the didactic unit;
- template of teacher's evaluation referred to the quality of the interactions produced during the development of the didactic unit;
- reinforcement, amplification, and recuperation activities;
- work index cards made by the teacher that will include: *6 questions* referred to conceptual contents and /or procedure contents; *4 problems* regarding the developed didactic unit. The number of work index cards per each didactic unit will depend on its characteristics and the aspects that it approaches.

Sequence of Didactic Units

Taking into consideration the principles that have been identified in the preceding points, we distinguish three different moments in the sequence of didactic units that we propose; each of these moments is characterized by certain teaching and learning strategies.

Figure 1 summarizes, for guidance, the steps to follow in each of the stages in which we have subdivided the development of a didactic unit: at the beginning, during and at the end.

Objectives of the Collaborative Research Action

In accordance with the previously executed layouts, we have designed a methodological proposal of class intervention for the area of Mathematics in one of the cycles of Secondary Education in Spain (14/16 years old) (MEC, 1990). It is based on the co-operative learning principles that we aim at testing and valuing through the collaborative research action (Blazquez, 1992), with the following objectives:

- to contrast the efficiency of co-operative learning as an alternative methodological strategy to attend to students' diversity in an ordinary classroom;
- to analyze the theoretical and methodological cores on which students' interaction and their repercussions on school learning are based;
- to make new theoretical contributions that complement the existing ones about co-operative learning.

At the same time, we want to draw conclusions for the initial and continuous training of Secondary Education teachers in general and of Mathematics teachers in particular, who are interested in the fundaments and techniques of co-operative learning.

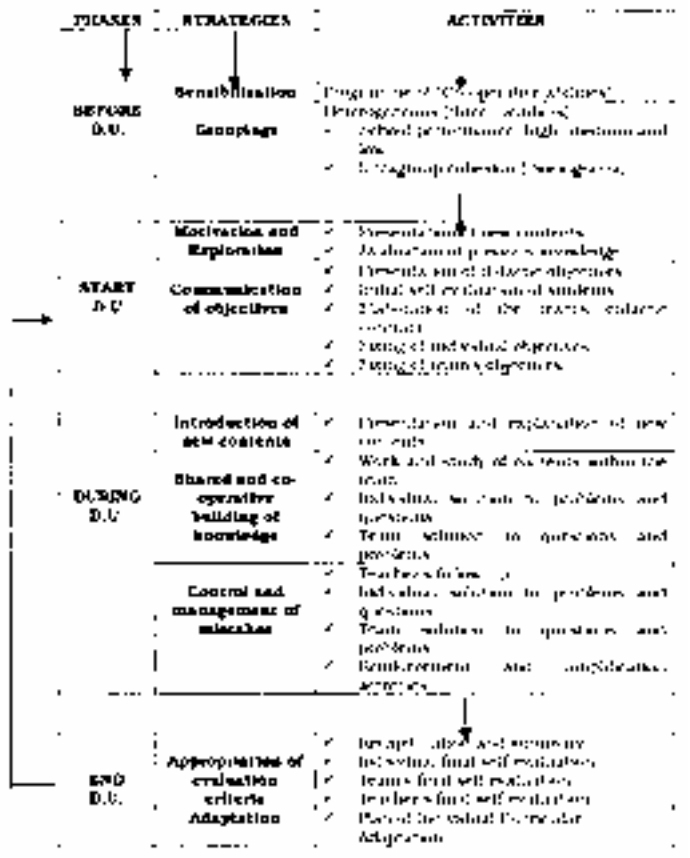

Figure 1. Phases, strategies and activities of the AMEC.

Shared Commitment to Improve the Practice

Following our proposal, the research is based on a process of collaborative research-action that, from the agreed assumptions, introduces teachers that participate in a real situation of research:

- We start from a design that generates from a problem verified by everybody in their classrooms, which is the product of group discussion and the shared experience by all members in the use of techniques of co-operative learning; we confer a decisive protagonism to all of them.
- Teachers play the role of controllers of the methodological proposal when they experience it in their classrooms proposing and promoting, by common consent, modifications and alternatives to the initial proposal from a collaborative position (Pérez, 1990).
- With our research, we aim at provoking personal, social and even organizational short-term changes in classrooms by means of a task of systematic divulgance.
- The team of teachers and students has been co-responsible in a series of strategies that allow, from action and reflect, to work together taking collaborative decisions.

By common consent, we aimed at:

- answering the problematic situation perceived in each of their contexts;
- participating from the whole process, since all participants have a direct role in the development, analysis and evolution of the research;
- having the participants, teachers and students, as research's beneficiaries by means of the immediate application of the discoveries found;
- creating a body of knowledge available to the whole educational community.

From this perspective, and after the agreements mentioned, our research work has been developed during a complete school year through three research cycles in which Mathematics teachers in secondary education have experienced, with students from 14 to 16 years, three didactic units made by all the team's members that have participated in the research. The selected topics were: 'Equations', 'Functions', and 'Areas and volumes of geometrical bodies'. In order to study them, the five classmates used the AMEC method.

On the other hand, we consider that the previous training of participating teachers was essential to develop appropriately the objectives proposed in our research.

From this perspective, we believe that the 'transference' possibilities of the learning obtained are high if the formative actions include the phases of theory, demonstration, simulation, practice and reflection.

Thus, during the previous trimester to the beginning of the research, they were given in weekly meetings a basic bibliography to learn the theoretical foundation of co-operative learning, co-operative learning techniques that are most widely used, co-operative learning techniques in Mathematics and the initial methodological proposal to develop: 'Mathematics Learning in Co-operative Teams' (AMEC).

In these weekly meetings we reflected upon the analyzed documents and drew the corresponding conclusions. This whole process of initial training culminated in a practice/simulation in which researches developed the role of teachers in a dynamic of co-operative learning and participating teachers developed the role of students. From here, we considered that we were able to start our research and developed it in class (Figure 2).

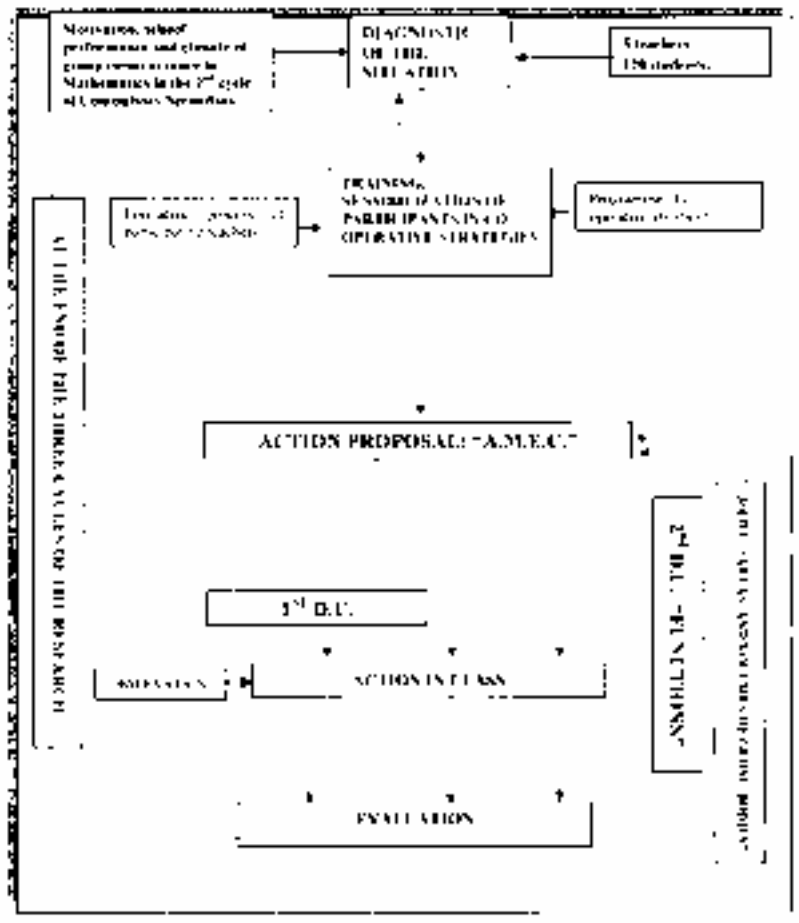

Figure 2. Phases that have been developed in the process of research action.

Data Analysis and Interpretation

The instruments used in the research to collect data were questionnaires, students and teachers' diaries, interviews with students and teachers, audio and video records, observation, teachers' reports and periodical work meetings.

In the analysis of questionnaires we have used a simple statistical treatment. However, in the process of treating the information obtained by means of diaries, interviews, audio and video records, work meetings and teachers' reports, we have established certain categories in the analysis units and we have made groupings of the categories into metacategories in order to summarize the data obtained.

In addition to this, we have analysed and interpreted the data with the help of the AQUAD v.5.6.1 programme of Professor Huber (1997) from the University of Tübingen.

As we all know, the credibility criteria in the qualitative researches is different from those used in quantitative researches and, what is more, according to others they are 'less accurate and more risky'. In short, as Glaser & Strauss (1967) pointed out some time ago, in the qualitative studies the readers themselves have to ultimately judge it.

However, before explaining the process followed to give credibility to our research, we want to underline that we have used a series of previous strategies to this process that aim at complementing and increasing the validity of the conclusions obtained.

To give the maximum credibility to our data and its interpretation, we have used the following procedures:

- triangulation of methods and perspectives, temporal and spatial;
- prolonged work: our research has been developed along a school year, with a phase of initial training and sensibilization for teachers and participating students in the research and, subsequently, developing three didactic units with a minimal duration of 12 sessions for each of them;
- participating and persistent observation: during the whole research we have developed a process of continuous interaction with the participants in the research by means of periodical meetings analyzing in common the perceptions obtained through the research process, postal and telephonic communications, audio and video records, gathering and codifying data, etc.

Context and Participants

In order to be coherent with our methodological proposal and considering that diversity is a source of personal and group enrichment, we have tried to ensure that the teachers chosen to participate in our research were as

heterogeneous as possible and they have only had one feature in common: teaching Mathematics to Secondary Education students.

We have preferred that teachers live different educational realities and that, at the same time, their training and experience were, if possible, also different. To achieve this, we consider that the suitable number of participants achieve to this diversity should be at least five teachers. In this sense, the selection criteria that we have used are: to come from different educational contexts and possess different teaching experience and, if possible, to come from a different initial training.

All of them have had complete availability to the research during a whole school year and they were involved sincerely on it. All of them wanted to know and put into practice in their classrooms new teaching and learning strategies that would allow them to improve, as much as possible, their students' attitudes to Mathematics, the climate of co-occurrence and the school performance.

The selection of students to participate in the research has been logically conditioned by the previous selection made by teachers.

The classrooms have been of 39, 25, 21, 25, and 12 students, respectively.

Transference Procedure

Even though we do not intend the obtained results to be generalized to the different teaching contexts presented, they can be a reference to those researchers interested in studying similar problems, or to teachers or teams of teachers who intend to develop innovative methodologies similar to ours. From this perspective, in order to ensure the greatest usage and transference of our research, we have made a meticulous description of contexts and an accurate report of the whole process. With the aim of providing this research with a wider reliability, we have foreseen:

- the coincidence in the composition and description of events;
- the answering validation or negotiation and participation of other researchers.

Comments on the Results of the Research

The main purpose of our work has been contrasting the influence of the AMEC Learning Mathematics in Co-operative teams in the following aspects: co-occurrence in class, motivation in Mathematics and school performance.

Students' Co-occurrence in Class

About half of students' opinions (47%) reveal a positive valuation of our methodological proposal. Nevertheless, there is also a significant number of statements that underline the difficulties and disadvantages of it (33%). It is

the disagreement that students show for the evaluation system established in our proposal.

It is important to underline the value that students give to co-operation, to give and receive help, and that is established from the dynamics generated in this methodology. The following student's opinion may summarize this idea:

> *I like this way of working more each day because we can help each other to understand the exercises better and if we were working individually and had doubts we could not help each other.*

The improvement of social relationships among students in class and its repercussion in the improvement of group co-occurrence is another of the aspects that are considered by students. These ideas are shown in the following opinions:

> *Students do relate better because teachers form the groups and you must work with the students he considers, so, in the end, one gets on well with people.*

One aspect that makes the functioning of the AMEC difficult is the scarce motivation in academic tasks that some students show. The next student describes it as follows:

> *But that two classmates work everyday and another is in class doing what he wants ... and I told him that he had to work, but I am not going to tell him every single day.*

Another student points out:

> *In my group we do everything only two because the other does not want to do anything ... sometimes the teacher has made him leave the class, he has only worked one day.*

Despite all these cases, not very numerous luckily, students recognize that quite often there is an improvement in the attitude and motivation in the subject. This student corroborates it saying: 'I think that some time ago it was only the teacher's explanation again and again, but now I feel excited (today we have Mathematics) because it is a more relaxed class.'

On the other hand, the following student points out: 'I will keep on saying that I like these classes more because they are more pleasant. Students behave better each day and they are more concentrated on Mathematics.'

Students also confer an important value to the improvement that this methodology produces in their performance: 'My performance has improved ... I have passed and I did not achieve it since last year. Classmates explain it with easier words and it helps a lot to pass. With last year's methodology I would not have passed.'

This student underlines: 'I think that the class' performance has improved, for me it has improved and can improve a lot more; being in groups is much easier.' As we can notice, mutual help among team mates

and the explanations they make to each other constitute an important factor to improve their performance.

The role that the teacher plays is also an important role in the AMEC, which calls the attention of students who realize this fact mainly when they compare it with their previous experience. Thus, the next student says:

> *The difference I find is that instead of explaining it to the whole class, the teacher explains it to the group if there is something we do not understand. We do the rest among ourselves and, however, other teachers want to do and explain everything themselves ... when all the groups have the same doubt he explains it to the whole class. When there is a doubt like that in other classes nobody dares to ask because we are ashamed. Well, if the teacher is very strict then we do not dare at all.*

Teachers' Attitude with Respect to the Experience

A third of teachers' opinions reflect the difficulties found when carrying out our methodology, but another third of them positively value the effects that the AMEC produces when is put into practice.

What teachers most value from the AMEC is the better attitude towards Mathematics that their students develop, as well as an improvement of the social relations established in the group-class. The improvement in the school performance of their students also occupies an important place in their statements.

Teachers focus the majority of difficulties in the structure of the task, especially because, even though the aim was to make a global valuation of the research process, they have eluded what happened through the third didactic unit experienced ('Areas y volumes of geometrical bodies'), which has generated interesting reflections about the contents to teach and the influence of students' previous knowledge. The difficulties generated by the scarce predisposition of some students occupy a less relevant place.

In order to make a deeper analysis of teachers' thought, Table I shows the five categories that occur more frequently in teachers. (Only one of them coincides with those with higher frequency of occurrence in students: 'Improvement of students' attitude'.)

Category	Frequency
Improvement of students' attitude	60
Difficulty of the Didactic Unit	59
Difficulties in the task	43
Proposal of modification of the structure of the task	34
Teacher's role	29

Table I. Categories with higher frequency of occurrence. Teachers' perspective.

The category that teachers emphasize more in the last cycle of the research is the one that refers to the improvement of the attitude to Mathematics and the improvement of students' motivation. Teachers state it as follows:

> *A great majority of students affirm that they prefer this methodology. I consider this very important because, at this age, one of the problems we must face is motivation; it is difficult to achieve that boys and girls feel comfortable in class, even more in Mathematics. From my point of view, to manage that students feel happy and motivated is a success of this methodology.*

Another teacher continues in the same vein stating:

> *Perhaps, the improvement of students' motivation is what I value most of this methodology and also that students value most. They say that they feel good and that fact in teenagers which are pure feeling! If they do not feel things is a bad sign ... Then, if we achieve that they feel ok in our classes we have made an important progress. Maybe this is what I value the most.*

However, teachers are also aware that there are students who do not improve their attitude and that this fact makes the development of our proposal difficult. Thus, this teacher comments:

> *Yes, but when a student says: – I am not going to study because I have not passed other subjects, so what am I going to study and make the effort in Mathematics? – . In such situations, it would be convenient that the good initial results that these students could obtain were an incentive to improve in the rest of subjects and that also teachers of other subjects wondered why.*

In any case, it is very difficult to make some students feel motivated. The next teacher describes it as follows:

> *I am talking of students who are completely indifferent, not only towards Mathematics. I think that many times the fact that these students form part of a certain group does not help them or their classmates at all.*

We also find on many occasions references to the positive valuation that teachers make about the co-operation among team mates. The following teacher summarizes it as follows:

> *Besides explaining things to each other, they do not hesitate to make the classmate repeat the explanation or to ask doubts that they would not ask to the teacher in the middle of an explanation for several reasons: shyness, not interrupting, for fear to ask silly thing, etc.*

This other teacher insists on the same arguments:

> *It promotes a more positive attitude towards the subject because it enables to find help when needed or to give it when asked, since it*

> *is less difficult asking a classmate than the teacher because of shyness or fear to ask something that would seem a silly thing and that would provoke the laugh of the rest.*

Of course, something may be done as this teacher points out:

> *Thus it is difficult to accept this way of working as something habitual, in which it is as important to help as being helped. It is a matter of patience and insistence to make the student work co-operatively because he is not going to do it easily any day now.*

In any case, teachers do develop proposals to improve the AMEC evaluation system; such proposals are basically focused on avoiding that any student feels disadvantaged.

Students' Motivation to Mathematics

Mathematics is one of the subjects that, initially, students like less. A teacher that has participated in the research states: '... the problem about Mathematics is that it is a dull subject and students feel especially indifferent ...'.

Nevertheless, 54% of students consider that their motivation to Mathematics has improved. Johnson & Johnson (1987) also reach this conclusion as they point out that working co-operatively increases the motivation to learning and activity in class.

In the same way, 77% of students underline that, with our methodology, Mathematics classes have been nicer. For instance, the next student points out, comparing it with her previous experience: 'I am in school since I was little and the classes are funnier this way, because before now, in Mathematics, the teacher always came in, explained using the blackboard and we did the exercises on our own which was much more boring than now.'

This student describes it as follows: 'Well, I like more the way they teach Mathematics this year because last year everything was individual and I did not understand a thing.'

However, 35% of students think that their motivation in Mathematics has not changed: 'I didn't like Mathematics before nor now, whatever we do.'

We must also underline that 11% of students consider that, with this methodology, their motivation in mathematics has decreased.

We believe that one of the factors that influences this valuation is the effect that the evaluation system that we have established produces on certain students, generally those with higher performance. The next student argues: 'I think this methodology is not positive because there are students who do not study much and those with a lower mark are best favoured since, as no average is made, the students that study more see their marks decrease and that is frustrating.'

Figure 3 shows the results that have been obtained about this issue from the answers to the questionnaire that was filled in by students at the end of the research.

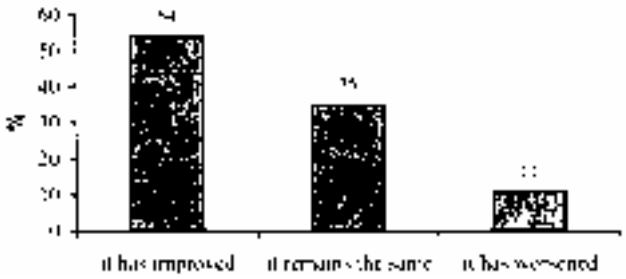

Figure 3. Motivation towards mathematics.

Students' Motivation from the Perspective of Teachers

All teachers that have participated in the research agree that their students' motivation in Mathematics has improved.

This is precisely one of the aspects that teachers value more and thus the next teacher points out: '... maybe, making a global valuation of this experience, what I value more positively is that it improves students' motivation very much. And this fact is shown in their responses. Well, they are happy and this is one of the positive things that I see in the AMEC, that students are motivated.'

Another teacher considers that co-operative strategies constitute a very important factor to neutralize rarefied situations in the classrooms (Alonso Tapia, 1997), especially in Secondary Education, which are originated by the school objectives and that we so frequently find in the mass media:

> *This method achieves that no student is left behind and quits the subject. Not only that, a student that quits a subject and does nothing is a source of conflicts and indiscipline in class. From my point of view, the best of this methodology is that there are no students that loose their motivation completely, since the methodology itself favours motivation.*

The following teacher reflects upon how the AMEC also influences a different type of students by improving their motivation. These are students with a low self-confidence in the development of mathematical tasks:

> *I have seen that those students that considered themselves unable to study Mathematics have advanced and improved their motivation...at least I am very happy because students who were not interested in Mathematics have felt an illusion when they have realized that they can follow the explanations of their classmates.*

A different teacher points out:

> *Motivation in Mathematics increases because it is a new way of working. The student feels more supported and is less afraid to ask. This provokes that he does not disconnect and continues to pay attention in class. In other occasions, more than motivation in the subject, this way avoids its decrease or even that the student finds easier to study Mathematics.*

The improvement of students' motivation in Mathematics is highly related to a greater amenity of classes and most students see it that way. Teachers coincide on this appreciation as well. The possibility that the AMEC offers to combine individual work with teamwork and group work helps to ensure that the classes are not routine and this fact is highly valued by teachers as well as students.

The following teacher correctly defines what the characteristics are: '… The AMEC does not intend us to constantly work in co-operative teams, but to alternate and combine the individual work with the work within the group-class and in co-operative teams.'

Evaluation Problems

Some students show a notable disagreement with the evaluation criteria established in the AMEC and teachers also reflect it. The next teacher summarizes it:

> *One of the most important disadvantages that students find is the evaluation method and those students with a higher performance do not consider fair to have to lower their marks just because the rest of the group has not obtained better results, and this is emphasized when a group member shows lack of interest in the subject or does not respect the work of others.*

Teachers find in this issue a justification of the difficulties that students show in this field: 'The system has indeed caused that the student only works to obtain a mark and there are few students with intrinsic motivation, that is to say, that work to learn how to learn.'

The following teacher adds:

> *I also see the influence of the family here. When they go home and their father says –If you pass I buy you a bicycle-. It is difficult to deal with this aspect because it is in the society. We have also considered it many times in the evaluations: How are we going to fight against the society, against the predominant culture, against parents? If they live this situation there is little we can do.*

The disagreement with the AMEC evaluating method is important among some students, especially those with a higher performance. To share the mark with the members of the teams, even though its influence on the student's final mark is minimal, has been greatly answered. The next comment made by a student summarizes this situation: 'I think this

methodology is positive because we learn to work in teams, but, on the other hand, some students benefit from others and those who obtain low marks see them raise whereas those who obtain good marks see them decrease.'

The next student coincides on the previous opinion: 'With respect to co-operation I think is positive, but with respect to the results and marks I do not think so since students that study less are benefited and those who study more are not.'

Students' Academic Performance

Students' academic performance in Compulsory Secondary Education is an issue that occupies many pages in specialized and non-specialized publications. The official statistics underline that more than 25% of students do not obtain the certificate of Graduate in Secondary Education. This percentage increases depending on the area; in the area of Mathematics we find the greatest number of failures, about 45%.

During the research process, all teachers have agreed that with the AMEC the academic performance of students generally improves, that the preparation of the knowledge test is easier than with the traditional methodology and that the explanations among students are easier to understand than their own.

The performance obtained in the three developed didactic units was as follows: in the didactic unit of 'Equations' 81% of the students passed, in 'Functions' 92% and in 'Areas and volumes of geom. bodies' 65% passed. As we can observe, the results obtained in the first two didactic units can be considered excellent, above all if we bear in mind that the number of pass marks in the didactic units previous to the AMEC did not reach 55%. On the contrary, the results obtained in the third and last didactic unit have been worse. The following teacher summarizes the possible causes as follows: 'The global results have been good enough in general, partly blurred by the results of the unit of areas and volumes. From my point of view, we can find three causes of such descent: a) difficulty of the topic, b) little time to develop it, and c) the tiredness that students show in this period of the school year'. The next teacher adds: 'With other methodology we would only have obtained worst results in this didactic unit, even under the same circumstances'.

In any case, globally, our methodological proposal AMEC has promoted an improvement of the academic performance of those students that have participated in the research as this teacher summarizes:

> *... we can observe that those students that normally present a high performance continue to show it, and that students with low or medium performance improve. We will always find situations in which performance does not improve, but it would not do it in any other way. However, it is difficult to find cases where performance gets worst.*

The New Role of Teachers

We must underline the extremely positive valuation that teachers participating in the research make of the AMEC as a motor in the improvement of their students' motivation in Mathematics. As a fact, the following words of a teacher that convey a final summary: 'With students of this age, one of the problems we must face is motivation. It is difficult to make them feel fine in class, even more difficult in Mathematics. To achieve that students feel glad and motivated is, from my point of view, a success of this methodology.'

One of the most significant problems that as teachers we must face in class, especially in Secondary Education, involves how to face the progressive deterioration of co-occurrence in class and we have found out that co-operative strategies can be an efficient tool, among others, to counteract it. Thus, we must try to make our colleagues know the potentialities of co-operative learning as the following teacher summarizes: 'I take the liberty of suggesting a proposal to introduce this type of strategies in centres. It implies presenting this methodology as a solution to the problem of isolation and/or giving up of the subject by students and, as a result, a solution to discipline problems that we so often find in classrooms nowadays.'

All the teachers that have participated in the research agree on the consideration that their students' performance in Mathematics has improved by putting the AMEC into practice. But they also agree that they have had to change their work habits or their usual way of working. Let's see some expressions: a teacher stresses the change produced in his role with this methodology and underlines: '... instead of explaining as usual, they establish the rhythm, why did I make a mistake here?, realize their own mistakes, on what part they fail more and they ask me to explain it.'

Students also underline this new role of teachers when they point out: 'When we were not able to solve something within the group, he came and solved it' or 'The class has checked the exercises and only when they did not understand something they asked the teacher to explain it.'

The following teacher describes in his diary his new role:

> *At the beginning, I encouraged them to start and clarified what they had to do in groups. To attend to people, without explaining, letting them ask for your help. To clarify a mistake that is repeated. Special attention to the most difficult ones. The aim is to persuade students that show a higher difficulty.*

This modification in the traditional role of teachers is also perceived by students: 'If we had any doubt within the group we asked him and he solved it.' The same student points out: 'If there was a common doubt in all the groups we asked the teacher and he explained it on the blackboard.' Another student says: 'The teacher helped and explained the doubts that a group had and was not able to solve.' As a result: 'We do not need the teacher as we

used to because classmates help you and the teacher does not need to be with us all the time.' 'The teacher has changed a bit, as we worked in groups!, he did not have to go one by one and explained it to the group even if a member understood it; this way made understanding easier. Thus, the relationships are better and he is on the watch for us.'

Thus, there is agreement in the conclusions that, among others, Serrano et al (1997) have reached in their research where they show the efficiency that, for school performance in the Mathematics area, implies the use of a model of co-operative learning.

The following teacher describes his experience very clearly:

> *In this group the improvement has been notable if we have in mind the high number of students that did not pass Mathematics last year and the number of those repeating the grade. With this methodology, it has been demonstrated that, working in co-operative groups, students have been motivated and at the end of the year more than a 60% of them will pass.*

The following teacher establishes a cause and effect relationship between the improvement of the motivation towards the subject and its performance: 'An improvement in the motivation in the subject provokes the existence of an improvement in school performance. The student works more and he feels motivated to follow a rhythm because of his classmates.'

Even with respect to the doubts about how our experience influences high level students, this teacher summarizes her colleagues' thought:

> *Despite the statistics, we can notice how those students that normally have a high performance continue to have it and those with low or medium performance improve. There will always be cases in which the performance does not improve, but it would not do it anyhow. However, it is difficult to find cases where it gets worse. These considerations are important enough to speak in favour of the AMEC.*

The factors that, according to all participants, influence the improvement of the mentioned results are among others the following:

- The structuring of the task in a 'tutoring' situation, which is a relevant characteristic of the AMEC; that is to say, the fact that a student has to teach or explain certain contents or problems to his colleagues in the group or that he has to listen carefully to their explanations requires a great involvement in the task, which promotes the development of quality cognitive strategies.
- The role that teachers perform in the AMEC allows them to detect more easily the personal characteristics of their students or the learning difficulties that they may encounter either at the group-class level, team level or individual level. This more individualized attention that the

teacher can give to his students adapting to their level of knowledge also favours the improvement of students' school performance.

Teachers' Training

Co-operative learning has been shown in numerous researches, as well as in the one we present here, as an efficient or alternative instrument, among others, to answer the problems of socialization, motivation and school performance that are often found in class (Díaz Aguado, 1996; Buchs & Butera, 2001).

We have also checked that, in the study and training plans of teachers, the study of co-operative learning is often approached in a tangential way and, in several circumstances and/or due to ignorance, co-operative techniques are not used with the desirable frequency in the light of the results obtained with them.

From this position, we agree with Salas (1998), when he emphasizes that the training plans of future teachers will possibly have to be reformulated in such a way that they acquire a more solid training in different didactic methods, including the co-operative, so that they can choose with more elements of cause and freedom. Thus, we take the liberty of suggesting a series of proposals in order for co-operative learning to be included within the training processes of teachers.

Contributions to Teachers' Training

Initial training. To incorporate in the Teacher Training Programmes, within the Faculties of Education, specific credits that focus on the theoretical foundation of Co-operative Learning, as well as the knowledge of its different techniques. In the same way, in the Pedagogical Qualification Courses (CAPs) directed to future Secondary Education teachers, to incorporate a module that develops the theoretical-practical knowledge about Co-operative Learning.

Continuous training of teachers. In the Teachers and Resources Centres (CPRs), most of the formative demands received are focused on the organization of activities that underline the knowledge of strategies to attend diversity. Co-operative learning and, more precisely, our methodological proposal have been underlined as a good measure to assist diversity in the ordinary classroom.

It would be positive to include courses about co-operative learning in the Teacher Training Programmes. In the same way, we think that the CPRs should emphasize those Training Projects in centres that wanted to develop strategies to attend diversity, incorporating co-operative learning in this self-formative process as a valid instrument for this aim, though not the only one.

One of the problems that co-operative methodologies must face is that their implantation in classrooms is usually anecdotal and, in any case, without a continuity character, being limited in many cases to willing and isolated experiences that prevent their underlying principles and values from being internalized and assumed by students and the rest of teachers. Obviously, the fact that there is only co-operative work in Mathematics will predictably have a minor repercussion on the rest of subjects and on the educational centre, which would have as a result the 'stumping' of their objectives.

In order to avoid this situation we suggest:

- Introducing the principles of co-operative learning at early ages, if possible in Infants Education and with continuity in the different educational stages. It is obvious that attempting to introduce the co-operative principles and values that this methodology underlines in fourteen year old students and older, as we do, is not easy having in mind that these values in particular, in the majority of cases, are the ones students have received throughout their school history.
- On numerous occasions, when analyzing the Educational Projects and Curricular Projects of centres, there is an explicit reference to the fact that one of their objectives is the development of co-operative strategies in their students. To this effect, we believe that if these objectives do not emerge from a perceived and assumed need by the educational community they will hardly be reflected on the daily performances. Thus, we consider that a good strategy to achieve it is to constitute teams of teachers from different centres in 'promotive groups' of co-operative learning in order to progressively introduce it and raise interest about it in the rest of the educational community.

General Conclusions

The greater interest in Mathematics basically arises because classes are nicer and students actively participate in their development by means of a co-operative dynamic that promotes teamwork as they develop collaborative and mutual helping attitudes.

It is evident, and thus students show it, that if compared to the traditional methodology that students are used to where they play a passive role, merely receiving contents, our methodological proposal is more attractive and stimulating.

On the other hand, we are sure that the majority of the students that show certain indifference towards the AMEC, stressing that their attitude and motivation towards Mathematics has decreased, are those that present a high performance and that feel disadvantaged for the established evaluation criteria. We must also recognize that, within human diversity, there are students that have assimilated individualist and/or competitive

values that, without being completely negative, make it difficult and sometimes impossible for them to assume the values that co-operative methodologies emphasize.

Through the theoretical revision made about different co-operative learning techniques, we have not observed any disagreement with the evaluation criteria used when, in the final mark of students, the consideration of the group average is contemplated. However, this has been one of the most questioned aspects by students in our research.

The students that feel more prejudiced are those with a high performance and they play a very important role in all this process where the task is structured in tutoring situation.

Thus, we think that we have to be very cautious when using evaluation strategies that students can consider prejudicial to their interests. Consequently, teachers interested in practising strategies based on co-operative learning must dedicate an important amount of time to reflect upon the evaluation system to use.

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