# A Cooperative Learning-based Strategy for Teaching Relational Algebra

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## ABSTRACT

This paper presents the design, implementation, and assessment of a cooperative learning-based teaching strategy to introduce relational algebra in an undergraduate database course. It has been implemented in four course sections across two semesters. The strategy was assessed from both students and teachers perspective. Assessment results show that between 78% and 92% of the students considered that the group work enriched their learning, providing support for the use of cooperative learning. Also, the results from a homework and an exam on the subject show an improvement on the students' learning of relational algebra.

## Categories and Subject Descriptors

H.2.1 [**Database Management**]: Logical Design—*data models*; H.2.3 [**Database Management**]: Languages—*query languages*; K.3.2 [**Computers and Education**]: Computer and Information Science Education—*computer science education*

## General Terms

Experimentation, Human Factors, Languages

## Keywords

Database, active learning, cooperative learning, relational algebra, experience report

## 1. INTRODUCTION

The course Databases I is a 4-credit-hour mandatory course in the 3rd year of the Bachelor of Science's in the Department of Computer and Information Science at the Universidad de Costa Rica. This course provides students with the necessary concepts to design, implement, and manipulate relational databases. It also offers an introduction to object-relational databases.


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The teaching methodology previously used in this course consisted on lecturing, with few opportunities for interaction among students (with the exception of laboratory practice sessions). The problem with such methodology was that students became bored in class and were eventually demotivated. This led us to question and rethink our approach to teaching, with one of the outcomes being the experiment hereby described. We designed, implemented and assessed a new teaching strategy based on cooperative learning (CL) for one of the course topics: relational algebra. The strategy divides the class in three *moments*, making use of formal and informal groups and the plenary group to foster student collaboration and learning.

We switched to CL as the basis of our teaching strategy for three main reasons: it was innovative within our course; it could potentially be applied to many other learning settings in the course; and there existed ample evidence on its effectiveness and benefits [1, 2, 3, 5, 6, 7, 8, 9, 10, 11], including some experiences in Engineering and Computer Science in particular.

## 2. THEORETICAL FRAMEWORK

The essence of CL, which lies in the formation of small groups for learning purposes, has a long history dating from the times of Socrates and Plato, and evolving with public-speaking masters such as Confucius, Buddha, and Jesus, who established guidelines for true teaching arising from human encounters [5]. Nowadays, in the context of school and university teaching, cooperative learning refers to the educational use of small groups that allow students to work together to improve their own learning and that of their peers [9]. Cooperative learning contrasts with traditional methodologies based on individualism and competition among students.

According to [5], teaching in small cooperative groups has three main goals: the development of communication strategies, the development of intellectual and professional competencies, and the personal growth of students. The teacher role is that of a mentor, guiding and facilitating learning. Johnson et al. [9] recommend that teachers structure five essential components in all educational activity: (*1*) positive interdependence, (*2*) promoter interaction, (*3*) individual responsibility, (*4*) interpersonal skills, and (*5*) group processing. Domingo [2] distinguishes two types of cooperative work groups that can be used in the classroom: informal and formal. Informal groups are formed to work for a short period of time, and serve to direct students attention to learning materials, while establishing a positive environ-

ment for learning. Formal groups are created to work on a specific task, and may span one or more classes. In formal groups, students work together to achieve their goals and each student is responsible for maximizing her learning and that of her peers [2].

CL has been extensively studied and increasingly applied in all levels of education and in many disciplines [7]. Research on the effects of CL have found that this methodology has both intellectual and attitudinal benefits for students. It has been shown that CL promotes cognitive achievement and academic performance, at least in comparison with the competitive and individualistic methods [7]. Other benefits of CL found in [2] are: it allows students to influence their own learning process, it facilitates the participation of all students, it offers a cozier and more friendly setting for learning, it increases student satisfaction with the learning experience, and it promotes positive attitudes towards the subject matter.

# 3. DESIGN OF THE STRATEGY

## 3.1 Learning Situation

The learning situation addressed by the strategy is that students understand the basics of relational algebra [4]. Such understanding can be built in three stages: first, introducing the topic of relational algebra; second, presenting the algebra operators, emphasizing in some of their key characteristics; and third, demonstrating how to use and combine these operators to solve queries in a relational database.

## 3.2 Rationale and Goals of the Strategy

In the past, the learning situation had been tackled primarily by lecturing, interspersed with a variation of problem-based learning where some example problems (i.e., translating user queries into relational algebra expressions) were solved by the teacher but students were not given the chance to attempt a solution by themselves in class. With this approach, students often confused operators and had difficulty to solve homework and test problems where they had to combine different operators in the same query.

The authors thought that one way in which students could gain a better grasp of relational operators was by leading the students to discover by themselves the most important characteristics of each operator so they could later discern when to use them. Cooperative Learning was considered a good fit for this purpose since it enables students to have an active role in building their knowledge and achieve learning through collaboration with their peers (guided by the teacher).

The goals of the teaching strategy were that students:

- Recognize the purpose of relational algebra.
- Be able to explain to their peers what some relational operators (that they study in depth) do.
- Be able to solve queries in a relational database using the relational operators.
- Respect and value the contributions of their peers when working on a group task.
- Collaborate in the construction and integration of knowledge, and in the generation of conclusions based on discussion and consensus.
- Assess their own learning as well as the group work and interaction.

## 3.3 Description of the Strategy

The strategy is designed to be applied in a session of 1 hour and 50 minutes in the regular classroom. It divides the class period in three *moments*, each having a corresponding activity which is specified in the form of a written *work guide* for the students.

### *First Moment.*

In the first moment, informal groups of 3 to 5 students are created to introduce the topic of relational algebra. These initial groups are formed by the students themselves so that the activity begins with an atmosphere of trust and friendship. The activity consists in asking the groups to: (*i*) discuss their conception of relational algebra, (*ii*) make an analogy in terms of operands, operators and results, with other known algebra, and (*iii*) comment on the result of their work in the plenary group (consisting of all students plus the teacher). All groups are given the same work guide. The estimated time for this activity is 30 minutes, distributed as follows: 15 minutes for the initial discussion and analogy construction, plus 15 minutes for commenting in the plenary group.

### *Second Moment.*

In the second moment, formal groups of 3 to 5 students are created for a detailed study of the relational operators. These groups are formed in advance by the teacher, seeking diversity of skills, personalities and gender in the groups. Every group receives a different work guide because each group is assigned a different set of relational operators. The activity consists in asking the students to: (*i*) read the material supplied on the assigned operators while trying to answer some given questions about the key characteristics of the operators, (*ii*) collaboratively solve the given exercises (as much as they can), and (*iii*) explain to the plenary group how the studied operators work and present the solution to relevant exercises. Along with the work guide, each group is given a reading, which is part of the assigned reading for the day, so students should be familiar with the subject (though they are not expected to master it). The estimated time for this activity is 1 hour and 10 minutes, distributed as follows: 35 minutes for studying the material and solving the exercises, plus 35 minutes for presenting to the plenary group.

### *Third Moment.*

In the third and last moment, students keep working in the same groups created during the second moment. The activity consists in asking the students to: (*i*) perform an assessment of the teaching strategy, (*ii*) self-assess their learning, and (*iii*) assess the cooperative work performed by them and their group peers. All groups are given the same evaluation guide. The estimated time for this activity is 10 minutes.

#### *3.3.1 Version 2: Variation of the Second Moment*

A second version of the strategy was developed after experimenting one semester with the first version and analyzing students' feedback. The new version introduced two changes to the second moment. The first change was that the teacher did not explicitly provide students with reading

material on the assigned operators because students were expected to have read the material prior to the class (pre-class readings were in use since the beginning of the semester), thus there was no need for students to read it again in class. However, they were free to consult the textbook at anytime. With this modification, more time could be devoted to peer discussion and exercise resolution. The second change was that instead of having one representative from each formal group present her operators to the plenary group, students were reorganized into new groups such that each group now had at least one member from each of the previous formal groups. In this new arrangement, each student became *the expert* on a set of operators within her group, and therefore was given the mission to convey to its peers its own knowledge about these operators (within a limited time). With this modification, all students had the opportunity to participate, they were highly motivated to understand their operators and be able to explain them to their peers.

# 4. IMPLEMENTATION

## 4.1 First Implementation

The original version of the strategy was implemented in two sections of the Database I course during the 7th week of the first semester of 2010, and it took the entire class session. A total of 24 students from Section 1 and 18 from Section 2 attended. This was the first of two classes devoted to the subject of relational algebra, thus, the strategy served to introduce the topic. The second class was used to work, in small groups, on a set of relational algebra exercises.

### *4.1.1 The Student Context*

Section 1 was composed of 3 women and 21 men, while Section 2 was composed 3 women and 15 men. The entire course population was composed of young students in their third year of the B.S. program, most of whom were taking the course for the first time. By the time the strategy was applied, students were used to work in groups, since they were involved in several group activities (e.g., exercise solving and team competitions) during previous sessions. Therefore, students were prepared to take on the new teaching strategy based on CL.

### *4.1.2 The Place Context*

Classes were taught in a small classroom located on the third (and top) floor of our Department building. This room has space for about 25 students; it has good lighting, a desktop computer and a video projector. The classroom poses some limitations for the learning and teaching process: (*i*) it gets hot, hence during summer time it is difficult to keep students' attention because of the high temperature inside the classroom, (*ii*) it does not isolate noise well, which essentially prevents from listening to the teacher or students in the presence of rain, (*iii*) it makes it difficult for students to mobilize (with their desks) within the classroom due to its small size.

### *4.1.3 The Time Context*

The class met twice a week for 1 hour and 50 minutes. The class time for Section 1 was 1 p. m. to 2:50 p. m. and for Section 2 was 5 p. m. to 6:50 p. m. None of these times were particularly conducive to learning since fatigue and sleepiness normally worsened after lunch (class time of Section 1) and towards the end of the labor day (class time of Section 2), which made even more necessary the use of teaching techniques that promote active student participation in class, minimizing the negative influence of the schedule.

## 4.2 Second Implementation

The second version of the strategy was implemented in two sections of the Database I course during the 7th week of the second semester of 2010, and it also lasted a class session. A total of 12 students from Section 1 and 9 from Section 2 attended. This was also the first of two classes devoted to the subject of relational algebra in the course.

### *4.2.1 The Student Context*

Section 1 was composed of 2 women and 14 men, while Section 2 was composed of 3 women and 13 men. Like in the previous semester, most students were young and most were taking the course for the first time. They were also used to work in groups but students from Section 2 were particularly quiet and little participative, which posed a challenge for the application of the teaching strategy.

### *4.2.2 The Place Context*

Classes were taught in a small classroom located on the third (and top) floor of our building, which presented similar conditions to the ones described in section 4.1.2.

### *4.2.3 The Time Context*

The class met twice a week for an hour and fifty minutes. The class time for Section 1 was 11 a. m. to 12:50 p. m. and for Section 2 was 3 p. m. to 4:50 p. m. We considered that such schedules were more conducive to learning than the ones from the previous semester, where the strategy was first implemented.

# 5. ASSESSMENT RESULTS

## 5.1 Students' Perspective

During the third moment of the teaching strategy, each student was given an evaluation guide with ten questions. From these questions, four aimed to evaluate the teaching strategy, two aimed to assess students' own learning, and four aimed to assess the cooperative work performed by the groups. Answers were anonymous. In what follows we present only the more relevant questions and their results.

### *5.1.1 Self-assessment of Learning*

Table 1 shows the students' assessment of their level of understanding regarding relational algebra (especially the operators). This table summarizes the responses to the multiple choice question "To what extent did you understand the concepts of relational algebra (especially the operators)?" across two implementations of the strategy and two sections in each implementation. In the first implementation, students asked if they could give two answers for this question: one for the relational operators they studied in detail in formal groups, and another for the operators presented by their peers to the plenary group. The teacher agreed, and this is why an extra column is shown for each section of the first implementation in Table 1; column labels $F$ and $P$ stand for formal group and plenary group. We can observe from Table 1 that in the first implementation, most students (79%

**Table 1: Students' level of understanding.**

| | 1st Implementation | | | | 2nd Implementation | |
|---|---|---|---|---|---|---|
| | Section 1 | | Section 2 | | Section 1 | Section 2 |
| | $F$ | $P$ | $F$ | $P$ | $F$ | $F$ |
| $> 70\%$ | 19 | 4 | 16 | 6 | 6 | 7 |
| 30% to 70% | 4 | 17 | 1 | 10 | 6 | 2 |
| $< 30\%$ | 1 | 3 | 1 | 2 | 0 | 0 |

**Table 2: Learning enrichment through group work.**

| | 1st Implementation | | 2nd Implementation | |
|---|---|---|---|---|
| | Section 1 | Section 2 | Section 1 | Section 2 |
| Yes | 22 | 14 | 11 | 7 |
| No | 1 | 3 | 1 | 2 |
| Blank | 1 | 1 | 0 | 0 |

in Section 1 and 89% in Section 2) attained a level of understanding beyond 70% for the operators studied in formal groups, but for the operators that were presented in the plenary group, a large percentage of students (71% in Section 1 and 56% in Section 2) attained a level of understanding between 30% and 70%, and a non-negligible percentage of students (12% in Section 1 and 11% in Section 2) even attained an understanding of less than 30%.

In the second implementation, students did not request to give separate answers, which we attribute to the fact that the strategy was modified such that the plenary group activity was replaced by another formal group activity. Therefore, the results for the second implementation indicate the overall level of understanding (both for the operators studied in the first formal group and for the operators explained by their peers in the second formal group). We can see in Table 1 that in the second implementation all students considered that their level of understanding was at least 30%, and even a large portion of the students (50% in Section 1 and 78% in Section 2) considered that their level of understanding was higher than 70%. An interesting finding is that the overall level of understanding improved from the first implementation to the second, since no students chose the "less than 30%" option in either section, and only a few students wrote comments about not being able to understand what their peers explained (compared to the first implementation, where many students wrote such negative comments).

Table 2 summarizes the responses to the question "Do you think that the group work enriched your learning?" With this question, not only we assessed students' learning but also validated the choice of cooperative learning as the basis for the teaching strategy. In both implementations, the vast majority of students answered positively (between 78% and 92%, depending on the section). This provides evidence for cooperative group work being a positive and enriching factor for learning.

### 5.1.2 Assessment of Cooperative Group Work

Table 3 shows the responses to the multiple-choice question "How do you rate the work performed by your group?" For both implementations, the majority of the students (between 67% and 78%, depending on the section) rated the group work as *good*.

Table 4 shows the students' answers to the question "Did you like how the group interacted?" Since this was not a multiple choice question but a free-form one, student answers were classified in four categories: Yes, No, Partway, Blank. With the exception of Section 2 from the second implementation (where only 67% of the students responded positively), more than 82% of the students in all other sections said they liked the way in which the group interacted.

**Table 3: Rating of group work.**

| | 1st Implementation | | 2nd Implementation | |
|---|---|---|---|---|
| | Section 1 | Section 2 | Section 1 | Section 2 |
| Good | 19 | 14 | 10 | 6 |
| Fair | 5 | 4 | 2 | 3 |
| Poor | 0 | 0 | 0 | 0 |

**Table 4: Student satisfaction with the group interaction.**

| | 1st Implementation | | 2nd Implementation | |
|---|---|---|---|---|
| | Section 1 | Section 2 | Section 1 | Section 2 |
| Yes | 21 | 15 | 11 | 6 |
| No | 2 | 3 | 0 | 2 |
| Partway | 0 | 0 | 1 | 1 |
| Blank | 1 | 0 | 0 | 0 |

### 5.1.3 Assessment of the Strategy

Table 5 summarizes the students' responses to the question "Did you like the way in which the class was developed?" which provides an assessment of the student satisfaction with the teaching strategy. Answers were free-format hence they were classified in three categories (Yes, No, Partway) for the purpose of presentation. In the first implementation a large majority of students said they liked the way in which the class session was developed (92% in Section 1 and 78% in Section 2). However, in the second implementation the percent of positive answers decreased to 75% in Section 1 and 56% in Section 2.

## 5.2 Teacher's Perspective

We used two quantitative instruments to evaluate the students' learning on relational algebra: a homework and a midterm exam. However, the second semester that the strategy was used there was no homework on relational algebra, so we only have homework grades for one of the semesters where the strategy was used. We also have homework grades for the semester prior to the first use of the strategy (there were 18 students in Section 1 and 13 in Section 2 that semester). Table 6 shows the mean and standard deviation of the homework grades, combining students from both sections, for the semester where the strategy was not used and the first semester where the strategy was used. The last column shows the result ($P$-value) of a two-tailed $t$-test assuming unequal variances ($F = 1.88$, $P = 0.03$) over the homework grades for both semesters, $t(50) = 1.98$. A $P$-

**Table 5: Student satisfaction with the teaching strategy.**

| | 1st Implementation | | 2nd Implementation | |
|---|---|---|---|---|
| | Section 1 | Section 2 | Section 1 | Section 2 |
| Yes | 22 | 14 | 9 | 5 |
| No | 1 | 2 | 2 | 2 |
| Partway | 1 | 2 | 1 | 2 |

**Table 6: Homework results.**

| Strategy not used | | Strategy used | | $t$-test |
|---|---|---|---|---|
| Mean | Std. dev. | Mean | Std. dev. | $P$ value |
| 68 | 36 | 83 | 26 | 0.053 |

**Table 7: Exam results.**

| 1st Implementation | | 2nd Implementation | |
|---|---|---|---|
| Mean | Std. dev. | Mean | Std. dev. |
| 88 | 16 | 80 | 23 |

value of 0.053 shows a moderate positive effect of the strategy over the students' understanding of relational algebra.

With respect to the midterm exam, it included one section of relational algebra. Table 7 shows the mean and standard deviation of the grades obtained by the students (from both sections) on the relational algebra section of the midterm exam for the two semesters where the strategy was applied. A mean of 80 or above is a good indicator of the high level of understanding achieved by the students through the teaching strategy. Unfortunately, we do not have comparative data from prior semesters where the strategy was not used. We have the overall exam grades, but comparing the overall grades would not lead to useful conclusions since several other topics were covered, and the topics covered in each exam varied across the semesters.

We also performed a qualitative assessment of the strategy based on the observed strengths and limitations. The main strengths of the strategy were that it (*i*) facilitated the interaction and collaboration among students; (*ii*) fostered the participation of all students; (*iii*) enabled students to construct their own knowledge based on readings, questions, exercises, and discussion with peers; and (*iv*) invited students to reflect on their own learning and the group work. On the other hand, a major limitation of the strategy was the large amount of time required to finish it, evidenced by complains of the students who said that they did not have enough time to complete all the exercises of the work guide. Using the traditional lecture approach, all the material was easily covered in a class session, but using the proposed strategy, a little more time was required, due to the increased student dynamism and participation. Another limitation came from the fact that not all students were effective communicators, meaning that it is possible that some students did not clearly explain their operators, leaving their peers confused or lacking some knowledge about them.

# 6. SUMMARY AND FUTURE WORK

A cooperative learning-based teaching strategy for relational algebra was presented. The design, implementation, and assessment of the strategy was described. Assessment of the strategy was performed from the students perspective through a survey-like evaluation guide, and from the teachers perspective through a midterm exam and a homework. Results from the students' assessment showed that the group work enriched their learning, providing support for the use of cooperative learning. Results from the teachers' assessment show an improvement on the students' learning of relational algebra.

In the future, we want to further improve the strategy in order to address some of its limitations, particularly the time aspect. We believe that by requiring students to read the material before class and enforcing it through a short online test, we will be able to reduce the amount of time needed for the *second moment* of the strategy. Additionally, we plan to explore the use of similar teaching strategies in other topics of the course, such as SQL, Entity-Relation model, and Relational model.

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