Algorithmic teaching and collaborative problem solving: case of a physical chemistry discipline

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Abstract. Based on an exploratory study carried out recently, and observations from several sessions of university teaching-learning in Morocco, we have found that the difficulties encountered by Moroccan teachers in scientific disciplines are mainly due to the problem of massification. This observation led us thereafter, to design a collaborative method of problem solving by algorithms, to bring more efficiency to teaching practices in graduate studies. Indeed, by forming a small groups of students, the teacher establishes an algorithm which he will follow during a whole activity, proposes to each group problems of variable complexity, then, he returns each time to the progress of this algorithm, in order to observe the progress of the work entrusted to the students groups. After integrating the method, observation grids and results from questionnaires, intended for an example of 70 students of the second year of Chemistry of Materials Science, at the Ben M’sik Faculty of Sciences in Casablanca, showed that the subjects are motivated by the method, and that the work within the group helped them to improve their learning. On the teacher's side, the choice of method has positively influenced these practices, particularly for the management of time and space in his teaching.

1. Introduction

These Moroccan universities, like those in other developing countries, are currently experiencing high demand for training. A demand that has led to overcrowding in the classes of these universities [1]: either according to statistics from the ministry of the higher education for the year 2016-2017, a workforce of 781505 students enrolled in 12 university establishments, with a capacity that does not exceed 484166 physical places. These numbers seen overall as detrimental to the teaching-learning action, increasingly complicate the task for the teacher-researchers who work within these establishments [2], that is because of the shortcomings and the insufficiency of the educational resources mobilized, their conditions of practice have became critical, and the policy which aims at the quality of education is always limited by encountering numerous obstacles which slow down its improvement and its progress [3] [4]. This often leads to universities that offer poor and limited quality services [5]. So, it is high time to review and renovate these teaching strategies in the different higher cycles, in order to make more improvements to teaching practices in practice, and to confirm quality training for the benefit of students in these cycles, while having a strong desire to take up the challenge of “massification”, which is practically omnipresent in all our universities [6]. By assuming that the method applied by the teacher in his class, is a key factor in improving student learning, we allow ourselves to advance a few questions of reflection on which this paper will be...
based: the strategy we propose can to overcome the difficulties linked to massification? Would the andragogy group be an effective solution? And finally, what will be the effects on teachers and their students at universities with the proving of this strategy?

2. Contextualization
With a series of observations, and an exploratory study, we have found in recent research work [7] the various physical chemistry activities carried out in the form of lectures, tutorials or experimental work, in the undergraduate cycle, do not go as it should, and that the so-called “classic” teaching strategies have shown their limits in the face of student enrollments which increase from one year to the next. When students are confronted with complex problems (explanatory questions, application exercises, etc.), their teacher often takes personal initiative and decides to solve them using his own method, without having the intention to get his students involved in the resolution, justifying that he does not have enough time to do so, and that he is obliged to give the solution personally to gain the maximum amount of time and move forward more quickly. Thus, we had the idea of establishing a strategy which could be very useful and profitable for the teaching-learning action within the “overloaded” faculties, while making the best possible use of the interactions between the learners [8], and their collective collaboration to solve the complex problems proposed by their teacher, whether at the tutorial level or at the experimental work level.

3. Collaborative work with algorithms
We start by defining the concept of collaborative learning which is, according to [9], “any learning activity carried out by a group of learners with a common goal, each being a source of information, motivation, interaction, mutual aid ... and each benefiting from the contributions of others, the synergy of the group and the help of a trainer facilitating individual and collective learning.” This definition clearly shows that collaborative learning is a form of formal peer learning [10], each of which, with its own learning strategy, benefits from the knowledge of its partners. The definition also shows how suitable this form of learning is for the training of adult learners, where the teacher-researcher intervenes physically only to facilitate and orient the work of heterogeneous groups of his learners. Indeed, by forming small groups of students in permanent interaction [11], collaborative learning manifests itself through a set of instructions and physical adjustments on the part of the teacher who takes into account the different institutional constraints [12]. So, by combining interaction and structuring, we have arrived at collaborative work by algorithms: it is a generic method allowing to solve problems whatever their input variables. This presupposes that several relevant inputs are determined beforehand, and which will be necessary for the design of the algorithm to be followed and for the management of the resolution task; namely: the size of the groups, the nature of the problems, the degree of complexity, the period of progress, the time necessary for the resolution, the implementation tools... etc.

4. Description of the method
In order to shed light on the algorithmic resolution process, and soon orient teachers' practices towards its easy use, we will try to present it in details, while outlining the various procedures to be implemented. Note that the method we propose is more particularly concerned with solving problems related to a pure scientific discipline (mathematics, physics, chemistry, biology, geology). Using algorithms written in an instruction prescription logic, the teacher develops and then follows a well-structured method, while proposing to each group problems of variable difficulty, he returns each time to the progress of its algorithm, in order to observe the progress of the students' work and outline the form of the questions to be asked during future interrogations or assessments. Then, this collaborative method of resolution gives each learner the opportunity to observe and internalize the strategy used by their peers, to actively participate in establishing a common strategy for the work of the whole group [11]. To illustrate what we have just described, here we offer an example of an algorithm that we have developed, and that can be adapted for any scientific discipline:
Begin

Inputs:
- Number of students in the group;
- Several exercises of varying difficulty;
- Meaning of difficulty: from the easiest to the most difficult;
- Estimated time: 45 minutes;
- Period: mid-semester I;

Procedure:
- Proposed exercise solved?
  - Go to the next exercise;
  - Otherwise: Exercise not resolved?
    - Offer an even easier exercise;

Outputs:
- Overview of the degree of complexity of the problems.
- Determination of the time required for resolution during the assessment.

End

5. Evaluation of the approach

5.1 Methodology
To check if our method has an impact on the learning of Moroccan students, especially in terms of motivation and performance, we designed a questionnaire for learners of electrolyte chemistry. This physico-chemical branch, has been taken as an example where massification appears strongly (more than 400 enrolled), is studied in all Moroccan science faculties for students of Matter of Chemistry Sciences (SMC), in the second year of the bachelor cycle (L2). Teacher-specific observation and analysis grids have also been developed to monitor the time and attitudes of groups with regard to each problem. Three phases marked our research. A first phase, or observation phase, was before the introduction of the method, and consisted in examination of the reactions and individual activities of the students faced with the problems posed by the teacher. This phase was also an opportunity to observe the teacher's behavior and practices with a group that reached 100 students in a tutorial session. Then, the second phase took place around the implementation of collaborative problem solving by algorithms. During this phase, we explained to the students the course and the objective of our approach, in which they will be engaged. Finally, the third phase aimed to assess the impact of the method on teacher and student performance using questionnaires and observation grids. Our sample consists of 70 responses that were obtained within the Ben M’sik Faculty of Sciences in Casablanca, and this directly after the end of the tutorials where the method was implemented.

5.2 Obtained results
Regarding group work, more than 63% of subjects consider it to improve their apprenticeship, thanks to their peers who help them solve the problems proposed by their teacher. This work is adapted to the needs of 77.6% of learners.

Figure 1. Responses to improving learning within the group

Figure 2. Responses related to adapting the collaborative resolution to individual learning needs
On the other hand, the collaboration method helped 84.5% of learners to solve difficult electrolyte problems, and therefore around 90% were motivated by the new collaborative method.

![Figure 3](image1.png)  
**Figure 3.** Does the collaboration method help to solve complex problems?

![Figure 4](image2.png)  
**Figure 4.** Motivation for the collaborative method

Finally, more than 79% of students want the collaboration method to be applied in all tutorials

![Figure 5](image3.png)  
**Figure 5.** Rate of learners wishing to integrate the collaborative method in their learning.

5.3 Discussion

Analysis of the data reveals that the algorithmic teaching method has brought about a lot of changes in student learning, which confirms the starting hypothesis of this research. Several factors can explain these changes. First, the novelty of the strategy, both for students and for their teacher, as well as its consideration of the personal learning needs of each student, may be behind the domination of the positive effects manifested by the strong motivation for its use. Such positive effects were confirmed by [11]. Second, the subdivision of the whole group into small sub-groups influences teaching practices. Indeed, the efficiency of the teaching work is clearly generated by the globality of the tasks performed, and the minimal time of collaborative resolution, obtained between different levels of reflection of the students within the same group (heterogeneous), instead of the monitoring of the individual progress of each student in their task. So we can say that there is a mutual relationship between the attitudes of students and this efficiency of teaching practices, in the treatment of complex scientific problems. Third, the student-student and student-problem interactions suggest that peers, whatever their level of proficiency in knowledge, influence in one way or another the group's behavior towards the problem confronted, hence the preference for group work by most students.

But if the rate of students motivated for the method is relatively high, a certain number of them rather consider group work to be inadequate for their learning. This can sometimes be explained by the birth of conflicts between students, either because of one or more inactive elements which belong to the same group, or by negative competition with the other groups.

6. Conclusion

We have tried in this paper to present a strategy of collaboration which will be very useful for teaching “large groups” within universities, while being based on learning through peers and using their daily...
interactions in a formal context. Given the results obtained, in terms of motivation and collaboration, we can say that this method is a part of the logic of improvement and renovation of teaching practices in these higher education establishments.

By the way of conclusion also, we can say that the present method would provide a double function in the event of its strategic integration (better choice of groups, total commitment of each element, and goodwill of the teachers). On the one hand, the professionalization of the profession of teacher-researcher using easy management of large numbers of staff, and on the other hand, the optimization of competition between students through direct involvement in their learning and the motivated confrontation of complex problems.

7. References

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