Experiencing a new method in teaching Databases using Blended eXtreme Apprenticeship.

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***Abstract*—The traditional approach of teaching Databases requires a great effort on the initial aspects of modeling and design that can negatively affect student's motivation. This consideration led us to propose a method able to motivate students. The paper presents an innovative method of teaching a Database course, as well as the results of its experience in an Italian high school. This method is based on a blended approach of the Extreme Apprenticeship methodology, jointly with a specific organization of the course topics, which, compared to the traditional organization, has been strongly adapted to the paradigm of Learning by Doing. Good results in terms of students' performance and in terms of level of learning perceived by the students have been achieved. The perceived level of learning achieved by the students has been measured through a questionnaire administered at the beginning, in the middle and at the end of the course.**

Blended eXtreme Apprenticeship; DataBase Teaching; Learning by Doing

I. INTRODUCTION

Traditionally, in Database (DB) courses design and modeling phases are covered in the initial part of the course; and the practical use, through exercises on a Data Base Management System (DBMS), is usually scheduled at the end of the course. Therefore, DB learning usually starts from abstract and complex design aspects, and ends with simple data applications. This approach requires a great initial effort on modeling and design, which are fully understood by the students only by applying them, at the end of all thematic blocks. This approach has strong negative consequences on teaching efficacy. These considerations are behind our proposal for a method that keeps students' motivation high, combined with a high level of learning perception of course topics. The method is based on a blended approach of the eXtreme Apprenticeship (XA) methodology, complemented by an organization of topics strongly adapted to the learning by doing paradigm. In the proposed method, all phases of DB design are experienced in parallel, being reinforced from the beginning by a large number of practical exercises.

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The paper is structured as follows. Section II presents the basic concepts of the XA methodology and a brief analysis of the traditional DB teaching. In Section III the context of the experience and the reasons that led us to the proposal of the new method are presented. In Section IV the structure of the proposed method is detailed. Section V presents the results of the experience. In section VI the final considerations and future work are presented.

II. BACKGROUND

A. eXtreme Apprenticeship

An innovative teaching methodology called eXtreme Apprenticeship (XA) was recently applied at the Free University of Bozen-Bolzano. This methodology has been developed in 2010 at the University of Helsinki, and applied in Introduction to Programming courses [14], showing significant improvements over traditional formats of teaching [12, 15]. The basic principles of XA are the following:

- learning through practice (Learning by Doing),
- formative assessment, carried out through a continuous bidirectional feedback between teacher and student.

XA is based on Cognitive Apprenticeship [4], which refers to the teaching method in old workshop, where the master first exemplifies the tasks, then drives the apprentices progressively to acquire autonomy [5]. XA is divided into three phases:

1. Modeling: The teacher provides, through working examples, a model of how an expert does the job.

2. Scaffolding: the student performs, after modeling phase, a number of exercises under the guidance of the master. Teacher support is based on Vygotsky's *Zone of Proximal Development* [16].

3. Fading: gradual reduction of the teacher support.

By carrying out a large amount of exercises with relatively small goals, the student has a continuous perception of his

cognitive progress, with a positive effect on self-esteem and self-efficacy. The teacher supports the students' motivation providing feedback, useful for improving his learning. Exercises proposed by XA contain in their text those theoretical basic information that is strictly necessary for immediately starting with the practice, and to gradually introduce, within the next exercises, the concepts necessary to achieve the intended cognitive objectives.

The adoption of XA in University courses led to a decrease in dropout rate, and an increase in the percentage and in grades of students who passed the exams [6, 7, 8, 9, 12, 15]. Dodero and Di Cerbo [9] developed a blended version of XA, as in previous blended teaching experiences [11]. In the blended approach an on-line setting has been implemented, where scaffolding is provided to the students by individual, asynchronous feedback messages. The results obtained with blended XA were positive, and comparable to those obtained with in-presence tuition and individual real time feedback by the original XA approach [12, 14, 15].

B. *Teaching Databases*

Traditionally, DB teaching proposes the phases of conceptual, logical and physical design in consecutive and separate blocks. This approach is based on the engineering principle of splitting what has to be represented in a DB (conceptual design) from its implementation (logical and physical design). Each phase provides a detailed and exhaustive discussion of every topic. The practice on a DBMS software is usually scheduled at the end of such a theoretical part, or it is interleaved with the theoretical part, resulting loosely interconnected with the theory. This teaching technique is commonly applied in Academia [2, 13] and moderately applied in high schools [1, 10] where other unplugged methodologies, typically targeted to primary schools, are also sometimes used [3].

However, a detailed discussion proposed in consecutive, loosely connected blocks can negatively impact on learning, namely on attention level and motivation of the students. Most students do not grasp an overview of all three topics, and often acquire just technical, non-connected skills. Moreover, the first thematic blocks of the DB theory require a sustained effort and mental abstraction by students, who only at a later stage will have a feedback through DBMS interaction.

III. A NEW TEACHING METHOD FOR DATABASES

This section presents the context of our experience and the reasons that led us to the proposal of the new method.

A. *The context of the experience*

The proposed method was applied in an evening class of an Italian High School in Finance and Marketing Administration. The evening course provides a selected number of topics and a reduced amount of lectures, offering a Computer Lab for just two hours a week. A key feature of the evening school is the extreme variety in terms of type and level of education of its participants. The class consists of 23 students including:

- a group of young age students, with good computer science skills;
- a group of older working students of varying age (from 20 to 50 years old), with extremely heterogeneous computer science skills;

Some issues related to this context are listed below:

- the diversity of skills and maturity of the students,
- the evening hours, which affect the level of attention and fatigue,
- the motivation, that depends on the achievement of very different objectives.

B. *Choosing the Method*

In such a heterogeneous context, where students' fatigue and motivation play a huge role in the dynamics of the lecture, the choice of teaching methods is crucial. Below we discuss the reasons that led us to adopting a new method, based on blended XA and on a revision of content scheduling.

1) *Methodological Aspects*

Firstly, literature has shown that XA strengthens students' motivation [7, 14]. They are encouraged both through the proposed exercises with small cognitive goals, and by teacher's support. Using XA, students perceive the continuing evolution of their learning, supporting their self-efficacy and self-esteem. Second, the method is based on formative assessment of the student. Through a continuous bidirectional feedback with the teacher, formative assessment leads all students to achieve good basic skills, because they receive, step by step, all information needed to achieve the cognitive goal, and to acquire good practices. Finally, XA is based on Learning by Doing, a modality that is suited to learning in the evening hours. Learning through computer lab activities emphasizes the centrality of the student, and fosters meta-cognitive and self-assessment attitudes, allowing the student to verify the result of his action in the lab. XA, as proposed in [14], prescribes that all the exercises are carried out in the lab, in presence of a teacher who provides real-time support. Dodero and Di Cerbo [9] proposed a blended version of XA, where activities are scheduled both in presence of the teacher and as on-line activities. In Blended XA, at first students attend a lab session with scaffolding, and later, there is a gradual decrease of in presence scaffolding in favor of on-line scaffolding. In the experience described in this paper the following blended XA strategy has been adopted: each week, in addition to the two hour lab, students were given a few exercises to be solved as homework, with on line support from the teacher, through a Moodle LMS platform.

2) *Scheduling Course Content*

Our method provides an innovative reorganization of course content, which differs from the traditional organization of many of DB courses, organized in phases according to a "horizontal" temporal sequence, ranging from the conceptual level to the physical level, and ending with a practical experience using a DBMS software. The new organization of topics is carried out by proposing exercises that engage the students to "vertically" work on the DB, ranging from the

conceptual design to the practical DBMS exercise in the same lab hour. In this way, students can grasp, from the very beginning, a complete overview of course topics, and understand how each topic contributes to the overall design of a DB.

IV. THE NEW METHOD STRUCTURE

This section details the structure of the proposed method. In our experience we adopted a new organization of topics, that vertically crossed the various DB design phases. As prescribed by XA, theoretical lectures have been replaced by lab sessions providing exercises. In each lab session, the first exercise was presented to the students, as a modeling phase done by the teacher: the students repeated the teacher's actions, first by drawing on paper the conceptual and logical models, then by implementing the practical part using pgAdminIII and PostgreSQL. The next exercises were carried out with the gradual decreasing support of the teacher (scaffolding and fading phase). To implement XA, the exercises have to:

- gradually propose higher cognitive goals,
- promote the acquisition of mastery to perform a task.

Therefore the exercises contained theoretical information and were designed as repetitive, to a certain extent. In the experience, three groups of exercises have been proposed for each topic, according to the following structure:

- the first exercise: an exercise with theoretical references, proposed in modeling phase. The teacher shows how she performs the exercise, leading the student to grasp the most significant aspects and to acquire proper procedures:
- the second group of exercises (Now you try it!): an exercise similar to the first one, carried out by the student with the support of the teacher. The exercise may contain new theoretical references and repeats the mechanisms proposed in the first exercise, with minor cognitive deviations. The intervention of the teacher can be scaffolding or fading;
- the third group of exercises (Try again!): further exercises requiring repetition of knowledge and skills already applied in the first two groups of exercises. Also in this case the intervention of the teacher can be scaffolding or fading.

Each exercise required the modeling of a reality of interest, adopting the following structure:

- ER Model;
- Relational Model;
- Creating tables (using SQL);
- Operations on tables (insertions, deletions, queries).

Each exercise was designed as a sequence of smaller exercises, to engage students at different stages of the design phase, and in DB manipulation and interrogation. As an example, an exercise proposed during the third lab was the following:

EXERCISE – Let us create a DB for a library that manages DVDs rental.

- Draw the ER diagram and the relational schema of the following database entities: (i) DVD, with Cod_dvd, Title and Duration attributes; (ii) CATEGORY, with Cod_category and Name attributes.
- Write the SQL code to create the DVD table, taking into account the following properties and constraints: (i) Cod_dvd: character type (5), not null; (ii) Title: character type (50), not null; (iii) Duration: integer, not null; (iv) Primary key constraint.
- Write the SQL code to create the CATEGORY table taking into account the following properties and constraints: (i) Cod_category: type character (3), not null; (ii) Name: type character (20), not null; (iii) Primary key constraint.
- Write the SQL code to insert in the DVD table the following data:

Cod_dvd	***Title***	***Duration***
D0100	The Blues Brothers	133
D0101	The Great Dictator	125
D0102	The Silence of Lambs	118

- Write the SQL code to insert in the CATEGORY table the following data:

Cod_category	***Name***
C001	Horror
C002	Thriller
C003	Comedy
C004	Action

- Extract Title and Duration from DVD table and sort by ascending title.
- Extract from the DVD table all data containing the word "Blues".

In each lab students solved 3 exercises, and got 1exercise as homework, to be delivered within 5 days. Before the next lab, the homework was corrected by the teacher and, if failed, there was still time to improve and deliver a flawless exercise. Students were free to choose the format and the method of delivery: as a text file, or on paper; by e-mail or by uploading the exercise in the personal folder of the school's LMS (Moodle). During the scaffolding and fading phases, the assessment of exercises resulted in a formative assessment, which is not intended to assign a grade, but to identify areas for improvement and to implement corrective strategies. For this reason the grades ranged between two possible values:

- 1: indicates that the learning objectives of the exercise have been met by the student.

- 0: indicates, on the contrary, that the learning objectives of the exercise were not met by the student.

V. RESULTS

This Section presents the results of the experience, which was conducted from December 2014 to April 2015, as 2 lab hours and a blended homework each week.

A. *Level of learning perceived by the students*

At the beginning, in the middle, and at the end of the course, an anonymous questionnaire was submitted to students in order to detect the initial, intermediate and final level of knowledge in DB topics in terms of perceived level of learning by the students. The questionnaire asked the student to self-assess on a Likert scale from 1 (level zero) to 5 (excellent level) w.r.t the following topics:

- Experience with a DBMS
- Ability to query a DB
- Knowledge of ER model
- Experience with SQL

Results from the initial questionnaire show that knowledge about the proposed topics was minimal; it mostly concerned tables and queries (see Fig. 1 and Fig. 2). Both the logical and conceptual design of a DB and the standard SQL language were unknown to most of the class (see Fig. 3 and Fig. 4). All the bar charts in this section show the number of students on the Y-axis and the level of perceived learning on the X-axis.

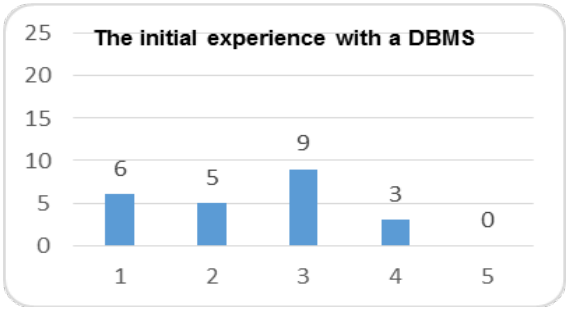

Figure 1. The initial experience with a DBMS perceived by the students

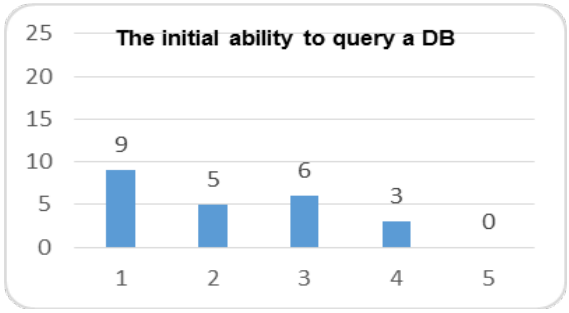

Figure 2. The initial ability to query a DB perceived by the students

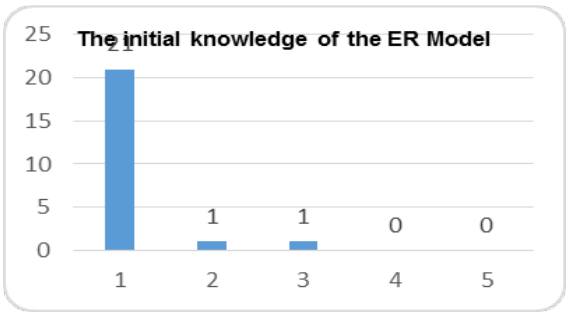

Figure 3. The initial knowledge of the ER Model perceived by the students

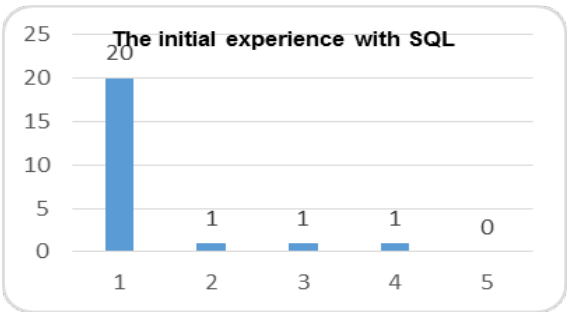

Figure 4. The initial experience with SQL perceived by the students

The same questionnaire was proposed to students for a mid-term evaluation. Results of the intermediate questionnaire show a significant increase in terms of perceived improvement, as well as a similar distribution of perceived levels, for each of the four topics proposed (see Fig. 5, Fig. 6, Fig. 7 and Fig. 8).

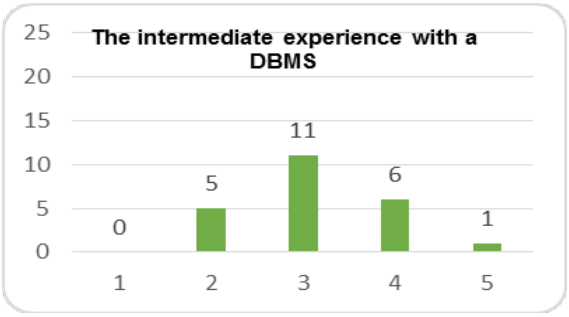

Figure 5. The intermediate experience with a DBMS perceived by the students

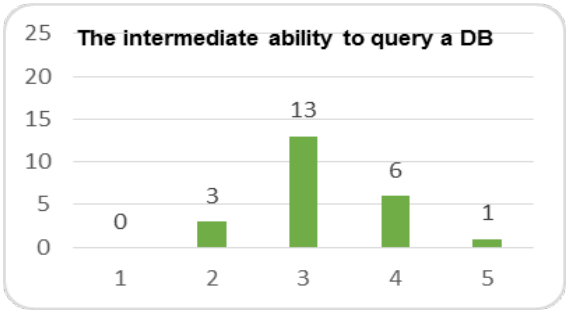

Figure 6. The intermediate ability to query a DB perceived by the students

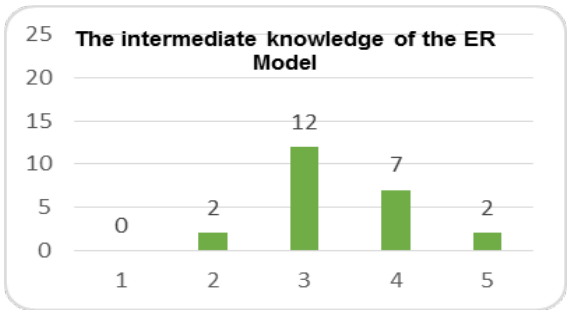

Figure 7. The intermediate knowledge of the ER Model perceived by the students

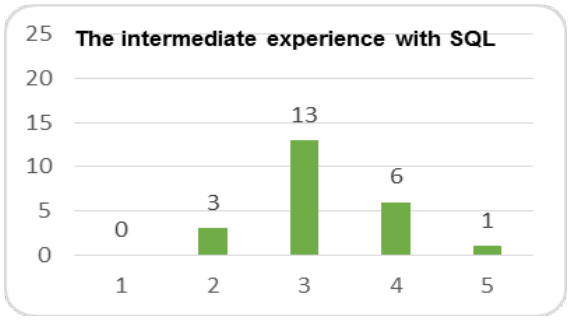

Figure 8. The intermediate experience with SQL perceived by the students

This good result is due to the new organization of the course topics: the phases of the DB design, and the use of a DBMS, have been proposed in parallel; thus, students' mastery about different aspects has increased simultaneously. Results of the intermediate questionnaire show that, for all topics, the number of students with the same level of perceived learning is homogeneous. The effectiveness of the simultaneous development of interconnected skills is even more evident noticing that in the last two topics (see Fig. 7 and Fig. 8), respectively, knowledge of the ER model and experience with SQL, the intermediate distribution shows a clear improvement compared to the initial situation (see Fig. 3 and Fig. 4). A further important result of the experience is highlighted in the intermediate questionnaire, where results show a Gaussian distribution shifted on medium-high values (3 and 4).

The same questionnaire was proposed to students for a final evaluation. It reveals two significant results of the experience. For all topics, the number of students with the same level of perceived learning is homogeneous (see Fig. 9, Fig. 10, Fig. 11 and Fig. 12). Also this result relates to the new organization of course topics, proposed in parallel. Results of the final questionnaire show that level of learning and self-efficacy perception of the students has a Gaussian distribution shifted on medium-high values (3, 4 and 5), which is higher w.r.t intermediate results. This depends on the application of the XA methodology and particularly to formative assessment that allows the whole class to obtain good results

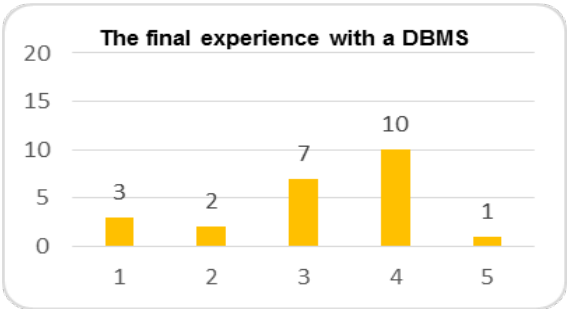

Figure 9. The final experience with a DBMS perceived by the students

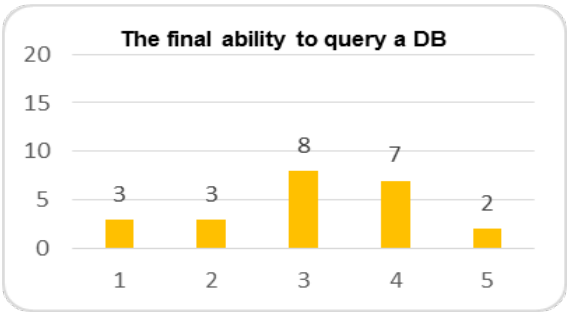

Figure 10. The final ability to query a DB perceived by the students

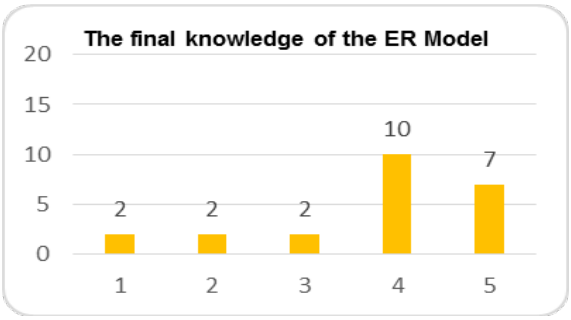

Figure 11. The final knowledge of the ER Model perceived by the students

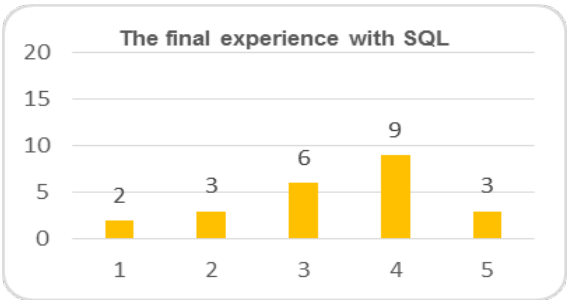

Figure 12. The final experience with SQL perceived by the students

For a better understanding of improvements in experience results in terms of level of learning perceived by the students in the initial, intermediate and final questionnaire, the following figures show a comparison among the specific questionnaire topics.

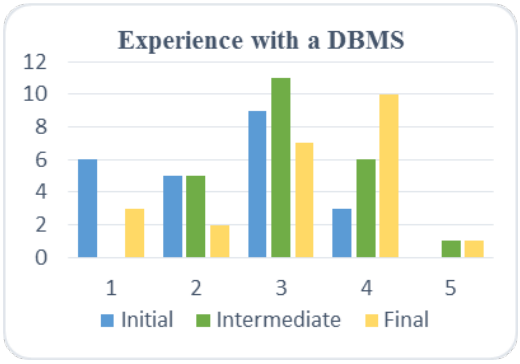

Figure 13. Comparison among initial, intermediate and final experience with a DBMS perceived by the students

Fig. 13 shows the comparison among initial, intermediate and final experience with a DBMS perceived by the students. About 80% of students are between 1 and 3 (low-medium values) in the initial questionnaire, and between 3 and 5 (medium-high values) in the intermediate and final questionnaires.

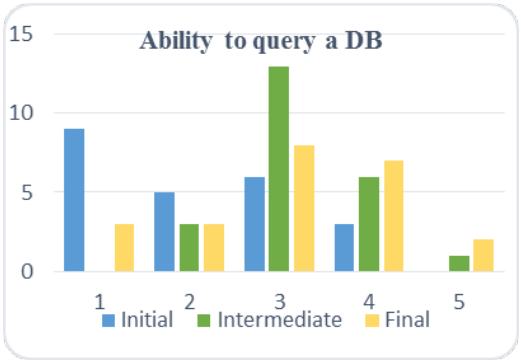

Figure 14. Comparison among initial, intermediate and final ability to query a DB perceived by the students

Fig. 14 compares initial, intermediate and final ability to query a DB as perceived by the students. About 85% of students are between 1 and 3 (low-medium values) in the initial questionnaire, and between 3 and 5 (medium-high values) in the intermediate questionnaire. In the final questionnaire about 75% of students is between 3 and 5 (medium-high values).

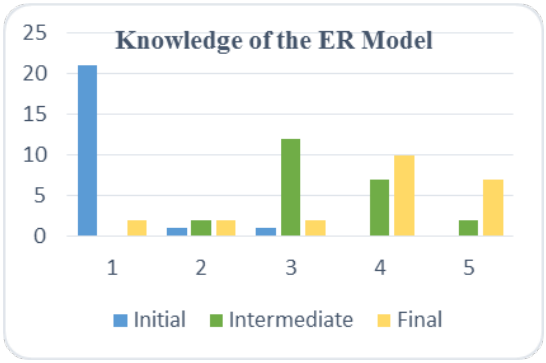

Figure 15. Comparison among initial, intermediate and final knowledge of the ER Model perceived by the students

Fig. 15 compares initial, intermediate and final knowledge of ER Model perceived by students. In particular, all the students are between 1 and 3 (low-medium values) in the initial questionnaire and about 80% of students are between 3 and 5 (medium-high values) in the intermediate and final questionnaires.

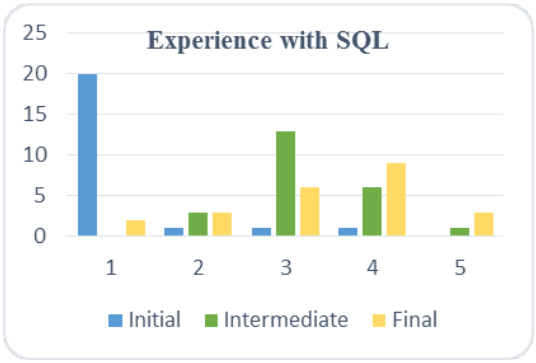

Figure 16. Comparison among initial, intermediate and final experience with SQL perceived by the students

Fig. 16 compares initial, intermediate and final experience with SQL perceived by students. About 100% of students is between 1 and 3 (low-medium values) in the initial questionnaire and about 80% of students are between 3 and 5 (medium-high values) in the intermediate and final questionnaires.

We remark that, for a correct interpretation of these results, the context of the experience has to be kept in mind. There was a single teacher in a class of 23 students, some of whom seldom attending the lectures. Optimal support for such a class would be typically given by one teacher every 10-15 students. Results achieved in the experience have shown, already at midterm, the effectiveness of the adopted method in terms of both summative evaluation results and self-efficacy perception of the students. Certainly, a better student/teachers ratio would allow for a shift on higher levels of the final results.

B. Summative Assessment

As per school quality plan, two summative assessments were planned, respectively, in the middle and end of the course. The format of the summative assessment was similar to those of the past years, i.e. no different performance criterion was applied because of XA. Fig. 17 shows the distribution of the grades of the intermediate and final assessments. The grades of both summative assessments, mostly in the medium-high range, with at least 70% of the grades between 7/10 and 9/10, suggest that the good perception of students, described in the previous sub-section, was transformed into a successful final evaluation (see Fig. 17, 2° assessment). As in the University courses, this good result is a consequence of the use of XA. Formative assessment fosters mastery acquisition in performing the task, allowing all students in the class to achieve good cognitive results.

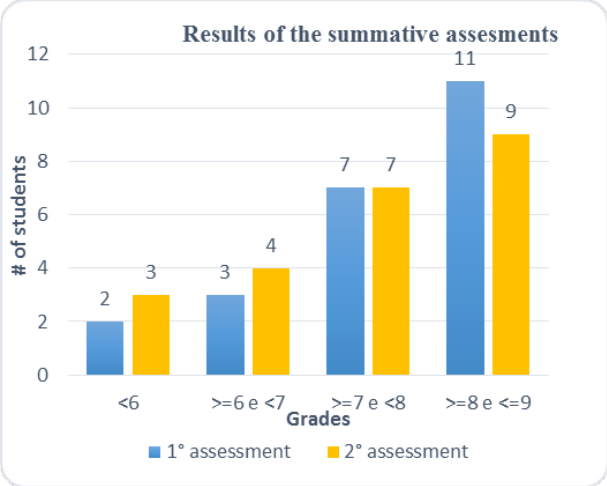

Figure 17. Distribution of grades in the two assessments

It is worth nothing that the trend of grades is very similar in the intermediate and final assessment. This highlights how XA achieves good results in a short period of time. The small decrease in grades in the second and final assessment is due to the complexity of the exercises. Finally, the systematically low grades were scored by students who seldom attended the course, compromising the creation of an effective relationship with the teacher and the outcome of the methodology. These results are very positive, especially in the light of the initial background of the students, which revealed a total lack of knowledge about the DB design and the SQL language.

VI. Conclusions and Future Works

In this paper a new teaching methodology for Database courses and its experience in an evening class of an Italian High School in Finance and Marketing Administration have been presented. In previous experiences, the application of both XA and blended XA has shown that this approach is suitable for different domains (Math, Programming, Operating Systems) as well as for different levels of students (High schools and Academia). In this work we describe as the blended XA together with a new organization of thematic blocks of exercises has achieved good cognitive results in a short time for most of the class also in the Database domain. Results have been measured in two ways, considering grades scored in two summative assessments, respectively, in the middle and end of the course, and collecting answers to a questionnaire to detect the level of perceived knowledge of DB topics by the students. The questionnaire was distributed three times, at the beginning, in the middle and at the end of the course. Results are very positive with respect to the initial situation, characterized by minimal knowledge on the subject. Finally, the experience showed that this approach performs best when teacher support is adequate. Therefore, in large high school classes the method is best applicable where co-teaching is possible. As future work, we plan to decrease the teacher's effort spent in formative assessment through automatic or semiautomatic exercise correction tools, to better support the teacher in the application of the method, and guaranteeing better scalability in large classes.

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