Scaling up a project-based SQL course

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***Abstract*— At Brest University, the SQL course of the CS bachelor degree is based on the constructivist paradigm and project-based learning. In 2015, we conducted research, based on a questionnaire, to assess how constructivist principles were perceived by students. Five years later, with the number of students having increased from 35 to 119, we had to return to a classical teaching method. To evaluate scaling up impact, we analyzed the redesigned system using the same questionnaire. Responses statistics for 2015 and 2020 are analyzed. Students' perceptions changed very little and the self-assessment results were very similar. However, comparing grades reveals that some students do not have the knowledge they claim to have, probably due to a lack of work favored by working in pairs.**

Keywords—SQL, project-based learning, self-assessment

I. INTRODUCTION

Many CS courses are characterized by inductive teaching methods and project-based learning, as is the SQL course in our CS Bachelor degree. The design and implementation of this course is based on Dwyer's learning paradigm [1]. Teaching is guided by objectives expressed in terms of learning outcomes. Practical work is carried out in a dedicated practicum. Evaluation is continuous and formative. In 2015, using a questionnaire, we analyzed the achievement of objectives as well as practices perception by the students [2]. With 119 students this year, it was necessary to return to a classical teaching method. In order to evaluate the impact of these scaling up measures, we analyzed the redesigned system using the same questionnaire. AY2014 and AY2019 statistics are used for analysis. We present in section II the project-based course and the redesigned course; in section III students' self-assessments; in section IV the characteristics of the practicum; in Section V students' roles.

II. COURSE STRUCTURE AND OBJECTIVES

A. SQL Course Structure

Learning SQL takes place in the 2nd year of CS bachelor degree, over 36 hours (3 ECTS). Expectations of the SQL course are formulated in terms of pedagogical objectives presented in tables I, II. An objective states the pedagogical purpose and the expected learning outcomes. Objectives achievement is evaluated through an information system project (1/3 of the final grade) and with a written exam based on the project (2/3 of the final grade). Project assessment is based on a competence scale: N Not acquired, P Partially acquired, L Largely acquired, F Fully acquired.

The project is a library management software. The expression of need contains four use cases with scenarios: informing the client (parameterized searches), managing a client (CRUD), managing loans (temporal processing), managing bibliographic records (meta-processing). The database is designed using a UML class diagram and manual translation into SQL-DDL. Processing design is based on use case scenarios. The realization is done with Oracle and its development tools, in SQL and PL/SQL. Tests are manual.

B. Pedagogical Practices of Project-based Learning

Flipped classroom. An half-hour "lecture" with a presentation of the concepts and teaching resources provided for the session, followed by an hour and a half of exercises in small groups with a few 5-minute spots, introduced on request during the exercise session.

All practical activities contribute to the project. The project is the common thread of the learning process. The practical work (20h) is used for the project; the difficulty is to limit the time for learning new knowledge in order to keep most of the time for mobilizing the knowledge in the project.

Life cycle. The project uses the cascade lifecycle: requirements, design, implementation, testing. Such a project is intended to provide students with a "learning by doing" approach about software development. Indeed, the project progress is sustained by software processes, exposing students to the topic – a pretty tough subject to teach. Putting a life cycle into practice promotes several characteristics of the learning paradigm: authenticity of learning situations, cognitive imbalance, interaction between theory and practice.

Continuous assessment. As soon as a deliverable is sufficiently advanced, students can request a diagnostic evaluation that quantifies their achievement and indicates the points that are faulty or need to be improved. Continuous assessment helps students to be conscious about software processes and improve the quality of work products.

C. Adaptation of Practices

This AY2019, there are 140 students enrolled, 119 in the SQL course. This demographic pressure has led us to return to a classical teaching paradigm, including a project.

Lectures. Lectures have been reintroduced for 12 hours (1/3 of the total time), with the usual drawbacks: absenteeism and lack of attention from the weakest students.

"Constrained" learning of the SQL language. Practical learning of SQL can no longer be intertwined with the project progress. 8 hours of practical work are devoted to writing an assignment of SQL queries without a computer, and another with, each assignment graded 1/4 of the project.

Project. The rest of the practical work (16h) is devoted to the library management project. Students are provided with a "survival kit" of the necessary knowledge, support sessions are used for the scaffolding and de-scaffolding of learning.

Life cycle. The requirements analysis was rudimentary. The design of the project was proposed as a bonus and only 1/3 of the students carried it out; the other students used the design proposed by the teacher. Tests were primitive. The size of the class has forced us to sacrifice the life cycle, and we lack sufficient time to understand the life cycle stages.

Continuous assessment. Diagnostic evaluation has been proposed, without teacher incentives. A few students used it, but not those who would have really benefited from it.

TABLE I. AY2014 SELF-ASSESSMENT OF OBJECTIVES ACHIEVEMENT

SQL course pedagogical objectives	N	P	L	F
Knowing SQL-LDD: creating and deleting tables and implementing a relational database in SQL.	-	0.07	0.43	0.50
Knowing and programming SQL search primitives: join, restriction, functions, grouping, sorting.	-	0.14	0.54	0.32
Knowing and programming SQL update primitives: inserting, deleting, modifying lines.	-	0.29	0.36	0.36
Knowing and programming PL/SQL procedural constructs and handling exceptions.	0.14	0.54	0.25	0.07
Developing the test sets needed for testing, using them to test programs according to the use case scenarios.	0.11	0.36	0.39	0.14

TABLE II. AY2019 SELF-ASSESSMENT OF OBJECTIVES ACHIEVEMENT

SQL course pedagogical objectives	N	P	L	F
Knowing SQL-LDD: creating and deleting tables and implementing a relational database in SQL.	-	0.12	0.45	0.44
Knowing and programming SQL search primitives: join, restriction, functions, grouping, sorting.	0.01	0.14	0.60	0.24
Knowing and programming SQL update primitives: inserting, deleting, modifying lines.	-	0.13	0.53	0.35
Knowing and programming PL/SQL procedural constructs and handling exceptions.	0.15	0.44	0.33	0.08
Developing the test sets needed for testing, using them to test programs according to the use case scenarios.	0.17	0.21	0.40	0.23

III. SELF-ASSESSMENT OF OBJECTIVES

Method and consent. Students are asked to agree to answer a questionnaire and are informed that the anonymous results are made public. In AY2014, 28 out of 35 students answered. In AY2019, 81 out of 119 students answered.

A. *Self-assessment statistics*

There are five objectives which are self-assessed by the students on the N-P-L-F scale. AY2014 self-assessments are shown in table I and AY2019 self-assessments in table II.

B. *Discussion*

Before beginning this study, the author had the pre-conception of a significant decrease in self-assessment of objectives. This turned out to be false and, according to the students, it even improved. The author's interpretation is that the classical teaching paradigm (lectures and practical work based on learning knowledge) is familiar to the students; the cognitive imbalance is reduced compared to the learning paradigm where one has to think about the required skills and they feel more comfortable with the teaching paradigm. Having made little use of diagnostic assessments, students did not receive feedback on their learning progress; the marks obtained are the proof, rather than mastery of learning, which can only be assessed in real project-based learning.

However, self-assessment, as practiced - after training - is a summative evaluation. In the future, self-assessment will have to be conducted before, during and after the project to become formative, as defined by McMillan and Hearn: “Self-assessment is more accurately defined as a process by which students 1) monitor and evaluate the quality of their thinking and behavior when learning and 2) identify strategies that improve their understanding and skills [3].”

C. *Correlation with summative evaluation*

Data. We worked on the marks given for the Library project and for the individual written SQL exam. The latter is trustworthy because it reflects the student's individual performance. We look at the correlations between the marks.

Comparison. The French system uses grades ranking from 0 to 20 with a grade of 10 being required to pass a subject. However, project assessment uses the N-P-L-F scale. N (Not achieved) and P (Partially Achieved) denote that the student does not master the competence (i.e. testing programs). L (Largely Achieved) and F (Fully Achieved) mean that the student acquired the competence. The conversion in the French system results in the mapping of marks: N → 0, P → 6.66, L → 13.33, and F → 20.

Hence 7 points (from P to L, or L to F) are a significant difference between marks. Figure 1 shows, for both AY, the average of project grades, the average of exam grades, the average of the difference between project and exam grades, and the percentage of students with a difference > 7. There were no significant differences in the standard deviations.

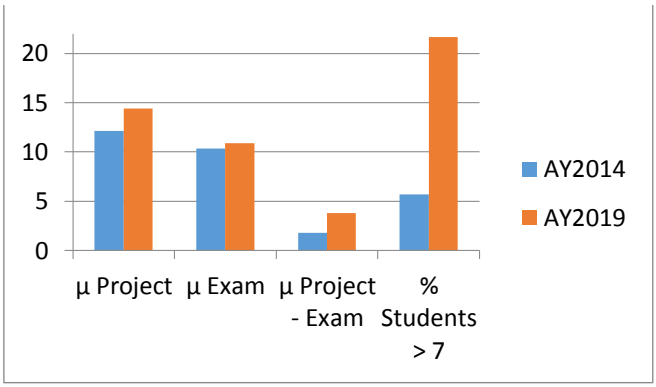

Fig. 1. AY2014 and AY2019 grade averages, and significant differences.

D. *Analysis*

In AY2014, the Library project was carried out individually. Students help each other, some students copy, consciously or unconsciously, parts of other students' work; but the project and exam marks are well correlated: only 2 students out of 35 (5.71%) have a difference considered problematic between project and written exam: the majority of students acquired a correct and lasting mastery of SQL.

In AY2019, the Library project was carried out in pairs (freely constituted). In some pairs, a student, consciously or unconsciously, may not work hard enough. The problem revealed by the statistics is that 26 out of 120 students (21.67%) have a difference between project and written exam marks and that difference is considered problematic.

A principle of the learning paradigm (see next section) is to promote consistency of learning and variation over time, whereas the teaching paradigm promotes consistency of time and variation in learning. In the previous format, with individual achievement and paced by diagnostic assessments, the student develops his or her skills and, ideally, devotes the necessary time to their acquisition. In this year's format, with a more rigid timetable and strong constraints on the submission of work in pairs, the difference between students cannot be taken into account and the logic of performance prevails over the logic of learning: in an unbalanced pair, the strongest student does most of the work.

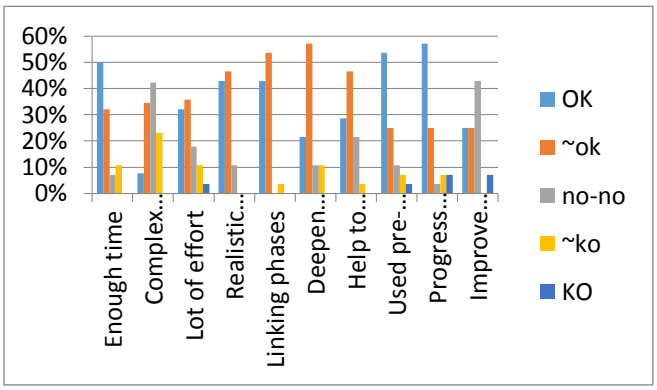

Fig. 2. AY2014 – assessment of the learning environment.

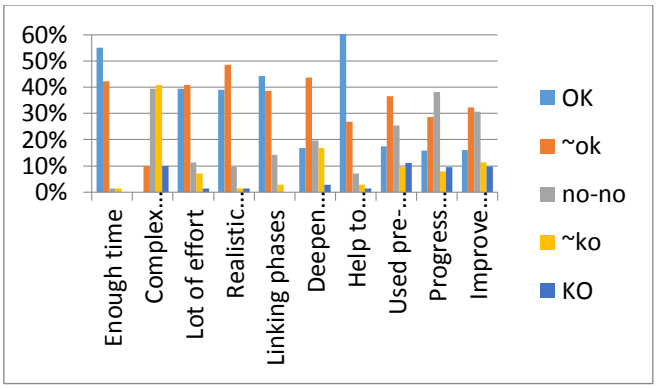

Fig. 3. AY2019 – assessment of the learning environment.

One student commented on his or her self-assessment: "Emphasis should be placed on group work in order to assemble everyone's knowledge rather than widening the gaps between grades with individual work that accentuates cheating among students." This makes a lot of sense. Next year the project will be divided into two parts, each part done individually and then assembled by the two students. The evaluation of the project, made by the teacher, will then be given to the students' pair so that the pair can distribute the points, either equally or differentially between the two students. The teacher may be asked to arbitrate.

IV. The practicum

A. A learning environment

Tardif defines the characteristics of a pedagogical environment consistent with the learning paradigm as follows [4]: constancy of learning and variation over time; cognitive imbalance; authenticity of learning situations; transdisciplinary; interaction between theory and practice; integration of assessments into learning situations. Our pedagogical approach derives from the project's goal "the act of thinking is regulated by its end [5]" where learning is the realization of work that leads to a goal: a small information system. Our approach also derives from the life cycle of a project its organizational dimension for the teacher, "a form of overall governance of the activity he [she] conducts [6]". The resources provided for the project are simplified but realistic versions of professional environments. The project has been designed to meet the first five criteria listed at the beginning of this section. Assessment is embedded in learning provided that students use the pre-correction mechanism or have regular interactions with the teacher. Transdisciplinary is not achievable in a CS Bachelor degree.

TABLE III. Pedagogical environment characteristics.

I had enough time to learn and realize the project.
I found the Library project to be complex.
I put a lot of effort into the Library project.
I found the Library project to be realistic.
I have a better understanding of links between specifications (use cases), design (table schema), SQL and PL/SQL programming and testing.
I had to deepen my knowledge to complete the project.
My work for the project helped me to understand the SQL course.
I used the pre-correction possibilities.
I progressed through the pre-corrections.
I was able to improve my working methods thanks to the pre-corrections.

B. Assessment of the environment characteristics

A part of the questionnaire aims to assess characteristics of the project pedagogical environment. The questions are given in table III. Students had 5 answers: Strongly agree (OK), Somewhat agree (~ok), Neither agree nor disagree (no-no), Somewhat disagree (~ko), Strongly disagree (KO).

AY2014. Figure 1 shows the students' responses. Follow a few comments collected. Everyone was able to go at his or her own pace and the project helps to understand the course. The timing at the beginning of the semester is ideal because the project is ambitious and requires a personal investment. Some people thought they would not succeed, but in the end they did. The man-machine interface work was frustrating: the students felt they did not have enough time for this part.

AY2019. Figure 2 shows the students' responses. Follow some comments. Students say they prefer a project-based approach. Many students found it difficult to learn procedural SQL (4th objective) because of the lack of time, the lack of classical practical work and the magnitude of the objective. Some students would have liked a larger project.

Analysis. There is no significant difference for the first four characteristics (time required, complexity, personal investment, realism). The current format is a mini-project based on the course rather than a stand-alone project, which means that the understanding of the phases of the life cycle and the deepening of knowledge is diminished but conversely it helps students better understand the course. Very few students used pre-corrections, so the last three characteristics are strongly decreased. Assessment is therefore no longer integrated into learning. We envisage replacing pre-corrections with self-assessment informed by peers. Boud says: "Peers provide rich information which is then used by individuals to make their own assessments [7]."

V. Students' roles

A. Roles definitions

A part of the questionnaire aims to assess how students play the roles based on the following Tardif's definitions [4] : **investigator**: I discussed with other students my questions about the project and/or I defended my solutions; **co-operator sometimes expert**: I explained some project points to other students and/or I had myself explanations from others; **clarifying actor**: I asked the teacher or other students in order to insure my good project understanding and to verify the adequacy of my proposals; **strategic users of available resources**: I used the available resources and/or supplementary resources and I verified their relevance.

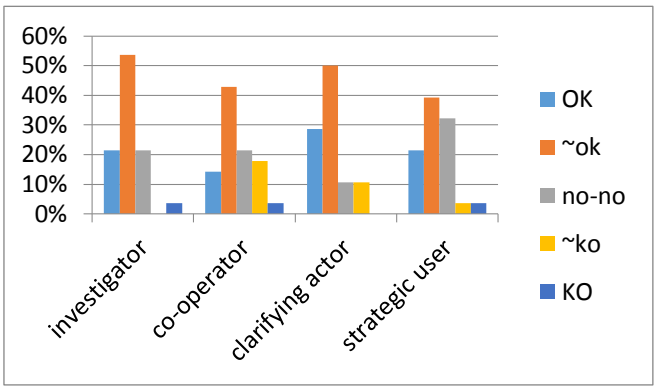

Figure 4. AY2014 students' roles assessment.

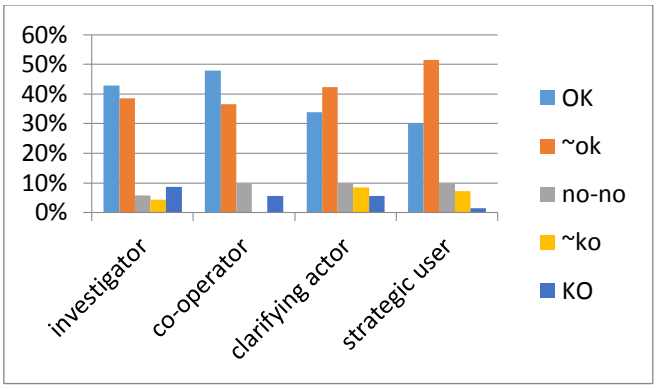

Figure 5. AY2019 students' roles assessment.

Figure 3 shows the AY2014 students' responses. Figure 4 shows the AY2019 students' responses. In AY2014, some students underestimate themselves and some definitions (co-operators, for instance) were seen as out of the reach and they could not use it to qualify themselves. Five years later, the new generation is much more self-confident.

B. Discussion

Investigator. According to Tardif "the investigator dares to make hypotheses that seem plausible to him or her, given his or her current base of knowledge and skills. [4]." The author's opinion is that AY2019 students do not investigate much but decide quickly based on what others do. The requirements analysis reflects this viewpoint; many students write their SQL queries without having read the corresponding requirements. The author has no idea how to structurally compel students to play the role.

Co-operator. Among the fundamental principles guiding cooperative learning are, first, that students are interdependent - group success depends on individual commitment - and, second, that they share a common goal [8], [9]. It is possible to divide the functionality of a project into several parts and assign each part to a student but it is difficult to prevent groups from adopting a Taylorist strategy. Aronson's Jigsaw teaching technique [10] could be used to encourage cooperation from students who have the same work to do. Inside a group, each student could have to test the part performed by his or her partner. Tests accuracy could be assessed by teachers and be part of the final grade.

Clarifying actor. Tardif mentions that students as clarifiers have a responsibility to question their peers and teachers, both about their own understanding and that of their peers. In a context of clarification, the author observed several times the interaction between students taking the form of conflict.

Strategic user. According to Tardif [4], particularly in the context of the use of information technology, students can become passive consumers of information. The author believes that the most common strategy is trial and error.

VI. Limits of the Study

In AY2014, five students volunteered to participate to the study. They collected nominative questionnaires and before anonymizing questionnaires, they related each questionnaire with the teacher's appreciation of objectives (based on the marks given to the project and the final exam). Thanks to the control procedure, we discovered that the AY2014 study suffered from a bias: because most students used the pre-correction mechanism, each deliverable went through a Author-Reader cycle that leads to improve them sufficiently to achieve a Largely Achieved or Fully Achieved level. However only "good" students were aware of the assistance provided by the teacher when a deliverable went through the cycle. Hence "good" students under assess themselves whereas "normal" students over assess themselves considering that the resulting deliverable is a witness of their achievement level.

Because AY2019 students used the pre-corrections very few, the bias is incidentally removed. But we need a way to correlate anonymous self-assessment with teacher's evaluation; it proved to be helpful in the previous study. Statistically speaking, AY2019 results are better than AY2014 results. Questionnaires were filled by students after the grading of the project and students knew their project grade but before they knew the final exam grade. As presented in figure 1, the project grades are good; students may lack objectivity while answering the questionnaire, at least those mentioned as problematic in section III.D.

VII. Conclusion

In AY2014, the questionnaire and the contribution of 5 students-authors indicated that the system promoted the construction of knowledge and know-how, encouraged students to be active, developed autonomy and a sense of achievement, improved evaluation and could develop mutual aid. Areas for improvement, at that time, were the structuring of the course, the lack of time and the platform for practical work which was considered discouraging.

In AY2019, students are overwhelmingly satisfied with the skills acquired, the teaching environment and the roles practiced. The revised system is due to the demographic necessity to return to a traditional paradigm of teaching. The learning paradigm has been much disruptive for students. The classical teaching method let them perform their "student job" well-established over the years, hence an enhanced self-satisfaction. Because they work in pairs, some students benefit from a project grade they do not deserve. We suspect also a lot of plagiarism. Individual assessment about the project and plagiarism detection should be added to the revised system. The question remains as to whether the learning achieved will be as sustainable, meaningful and transferable as that achieved in the learning paradigm.

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