

## Same Course, Two Methods of Learning: Assessment of the Student's Success

Jean-Paul Bailon<sup>(1)</sup> (Dept. of Mechanical Eng.), Bernard Clément (Dept. of Applied Mathematics and Industrial Eng.), Pierre G. Lafleur (Dean of Studies)  
Ecole Polytechnique, PO Box 6079, Station Centre-Ville  
Montréal (QC) Canada H3C 3A7

**Abstract:** This paper discusses the implementation of a self-directed learning strategy for instruction in an introductory materials science course. Student's performance metrics are directly compared to those from a more traditional lecture-oriented course. The raw data reveal that the students who have chosen the self-directed learning version of the course obtain a final mark higher than that obtained by the students who were taught in a conventional manner. Multi-variable analysis taking into account the GPA of the students, their level at their entry in the engineering program, the mark obtained in the common final exam and that obtained in quizzes were performed in order to point out the most influencing factor(s). It appears that the difference in student's success is mostly due to a better performance of the self-directed learning students in the continuous evaluation by computerised quizzes, the other variables having a negligible effect. We conclude that the main cause of the higher success of the self-directed learning students in the course should probably be the consequence of their attitude toward their responsibility in the learning process.

### 1. Introduction.

The course ING1035 – Materials (2 credits) is an introductory course to materials science and is compulsory for the freshmen enrolled in all the engineering programs offered by Ecole Polytechnique de Montréal (QC), Canada. Since January 2002, this course is offered in two versions, in which the students use an identical didactic material (manual, CD-Rom, guide, web sites with exercisers, videos, ...).

In the first version 1035C, which may be named “classic”, the students receive 3 h/week of formal lectures by a professor or lecturer. In the second version 1035D, which may be named “self-directed learning”, the students do not receive formal lectures and must learn by themselves. At the end of the semester, the students of 1035D (“self-directed learning” version) pass the same final written exam given to the students of 1035C (“classic” version). At the beginning of a semester, a student has the complete freedom to choose between the “classic” or the “self-directed learning” version; he cannot however switch from one version to the other in the course of the semester.

In this paper, the characteristics (similitude and difference) of the two versions will be firstly outlined. Then, we will present the results gathered during 6 consecutive semesters (from winter

---

<sup>(1)</sup> To whom all requests must be addressed (<mailto:jean-paul.bailon@polymtl.ca>)

2002 to autumn 2004), during which nearly 1 700 students have chosen the “classic” version (1035C) and 825 students have preferred the “self-directed learning” version of the course (1035D). Since these results clearly reveal that the students enrolled in the “self-directed learning” version obtain generally higher final marks than those obtained by the students enrolled in the “classic” version, we will present a multi-variables statistical analysis of these results in order to identify the factors which could explain these significant differences between the two versions of the course. The GPA of the students, their level at their entry in the engineering program, the mark obtained in the common final exam and that obtained in quizzes are among the main variables which are taken into account. We will conclude by proposing some reasons which might be invoked for explaining the difference in the student’s rate of success according to the two methods of learning.

2. Same Course, Two versions: Similitude and Difference.

In TABLE 1, the characteristics of the two versions of the course are summarized, as well as the particularities of each version.

Table 1: Characteristics of the two versions of the course ING1035 – Materials

Characteristics	1035C (“classic” version)	1035D (“self-learning” version)
Content	<ul style="list-style-type: none"> <li>• The course is divided in 12 units (lessons).</li> <li>• The student must complete 10 units.</li> <li>• Units 1 to 7 are compulsory and the student has to choose 3 units among Units 8 to 12.</li> </ul>	<ul style="list-style-type: none"> <li>• Identical to the “classic” version.</li> </ul>
Didactic Material	<ul style="list-style-type: none"> <li>• One reference manual<sup>1</sup> including a CD-Rom (230 screen pages of animations or videos, “book” of exercises with complete solutions, appendices, ...)</li> <li>• One guide of the course (in PDF format, <math>\cong</math> 50 pages) which describes in details how the course is organised, the content of each unit, the sections of the manual which must be read for each unit, the calendar of activities, the method of evaluation, etc.</li> <li>• One website, which recalls the general instructions, includes interactive exercisers and offers past exams with their solutions. Formal lectures (<math>\cong</math> 1 h each), presented by a professor and</li> </ul>	<ul style="list-style-type: none"> <li>• Identical to the “classic” version</li> <li>• Identical to the “classic” version, except for some specific details such as the method of evaluation or the calendar of activities.</li> <li>• Identical to the “classic” version.</li> </ul>

	summarizing the main topics of given unit, are available as streamed videos on the site.	
Instructional Mode	<ul style="list-style-type: none"> <li>• Conventional approach: 3 h/week of lecture given by a professor or a lecturer in a classroom.</li> <li>• Before the beginning of a new unit (lesson), the students must read the corresponding sections in the manual and answer some questions as homework.</li> <li>• A forum of discussion is opened on the website.</li> </ul>	<ul style="list-style-type: none"> <li>• “Self-directed learning” approach: the students do not receive formal lectures and must learn by themselves.</li> <li>• If they wish, the students may consult tutors (graduate students) available 8 h/week in a classroom.</li> <li>• Questions may also be posted on the forum of the website. These questions are answered daily by other students, by the tutors or by the professor in charge of the course.</li> </ul>
Evaluation	<ul style="list-style-type: none"> <li>• Ten (10) assignments associated with each unit and submitted before the beginning of a new unit (lesson). Only three (3) homework randomly selected are marked. Relative weight of homework for the final mark = <math>3 \times 5\% = 15\%</math>.</li> <li>• During the semester, two (2) written quizzes (1h 45 min each). The first quiz covers the units 1, 2 and 3, the second one the units 4 to 7. Relative weight of quizzes for the final mark = <math>2 \times 20\% = 40\%</math>.</li> <li>• One written final exam at the end of the semester (2h 30 min). The final exam is made up of some exercises covering the compulsory units (1 to 7) and includes one exercise for each optional unit (8 to 12). The exam is made of two parts: the first one dealing with the compulsory units (1 to 7) is weighted for 70 %, while the second one dealing with optional units (8 to 12) is weighted for 30%.. <b>The exercises on the compulsory units are the same that those proposed to the SL students (see the right</b></li> </ul>	<ul style="list-style-type: none"> <li>• The students pass 10 compulsory computerised quizzes (1 h. each). Each quiz, delivered on the WebCT platform, is available during three consecutive weeks (4 h/day x 4 days per week).</li> <li>• Each computerised quiz is made up of exercises very similar to those given in the quizzes or in the final exams of the “classic” version.</li> <li>• Ten to twenty different quizzes are associated with a given unit.</li> <li>• The relative weight of the quizzes is 70 % (<math>10 \times 7\%</math>) of the final mark for the course.</li> <li>• The students may pass 11 or 12 quizzes. In such a case, they can obtain a bonus since the final average mark for all the passed quizzes is obtained by summing up all the individuals marks and then dividing this sum by 10. The maximum value of this bonus represents 8.4 % of the final mark for the course.</li> <li>• One written final exam at the end of the semester (1h 45 min). The final exam is made up of exercises</li> </ul>

<p>Evaluation (cont.)</p>	<p><b>column).</b> The relative weight of the final exam for the final mark is <math>1 \times 45\% = 45\%</math>.</p> <ul style="list-style-type: none"> <li>In the final exam, students completing more than three (3) exercises associated to the optional units obtain a bonus, the maximum relative weight of which being up to 8 % of the final mark for the course.</li> </ul>	<p>covering the compulsory units (1 to 7) and is the <b>same first part of the exam</b> written by the students enrolled in the “classic” version. Relative weight of the final exam for the final mark = <math>1 \times 30\% = 30\%</math></p>
---------------------------	--	---

### 3. Results of compiled data.

The results compiled during six semesters (winter 2002 up to autumn 2004) were analysed either with Excel or with Statistica. FIGURE 1 shows the evolution of the number of students enrolled in each version of the course. When the “self-directed learning” version was offered for the first time at the semester of winter 2002, it was not intensively publicised; however since this version is now more and more popular, the ratio of students opting for the “self-directed learning” version in a given semester is closed to 45%.

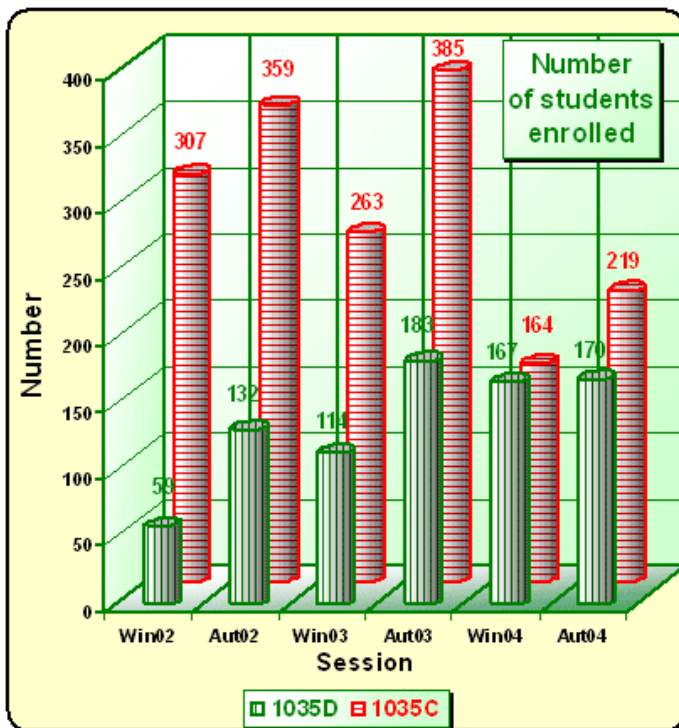


Figure 1: Evolution of the inscription in the two versions of the course ING1035.

FIGURES 2 and 3 present the histograms of the final grades obtained by the students during six consecutive semesters (from winter 2002 up to autumn 2004) for each version of the course. In these FIGURES, the “R” grade corresponds to the students who have officially withdrew

themselves from the course before the official deadline, while the “F\*” grade is for the students who did not complete the course without officially withdrawing (“drop-out” students).

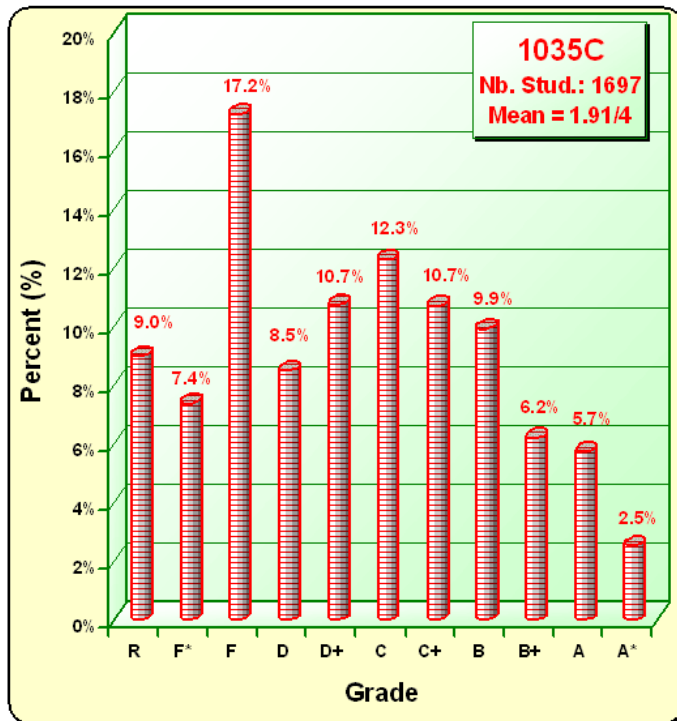


Figure 2: Distribution of the final grades for the students who have chosen the “classic” version (1035C).

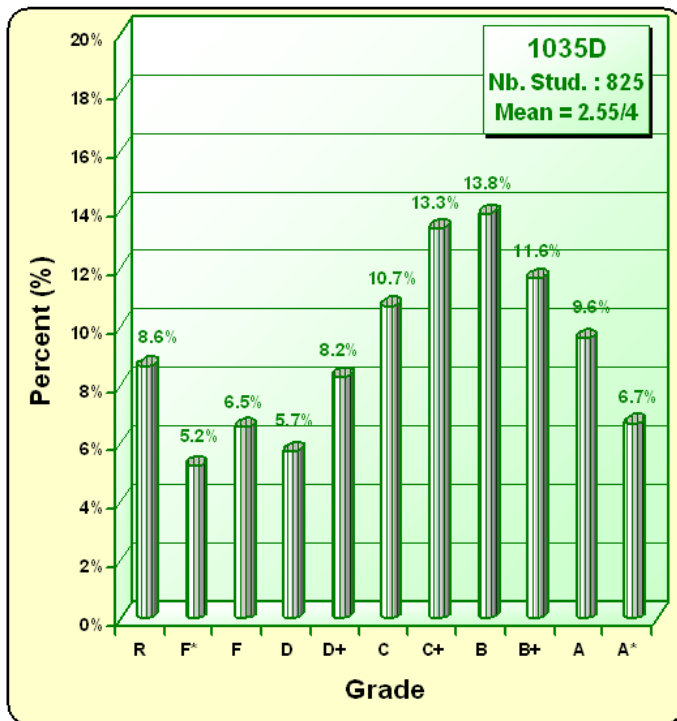


Figure 3: Distribution of the final grades for the students who have chosen the “self-learning” version (1035D).

When the grades presented in FIGURES 2 and 3 are translated into numerical values <sup>(2)</sup>, the evolution of the general mean for the ING1035 course is obtained and presented in FIGURE 4. For this figure, the students who have obtained a “R” or “F\*” grade are excluded of the statistics.

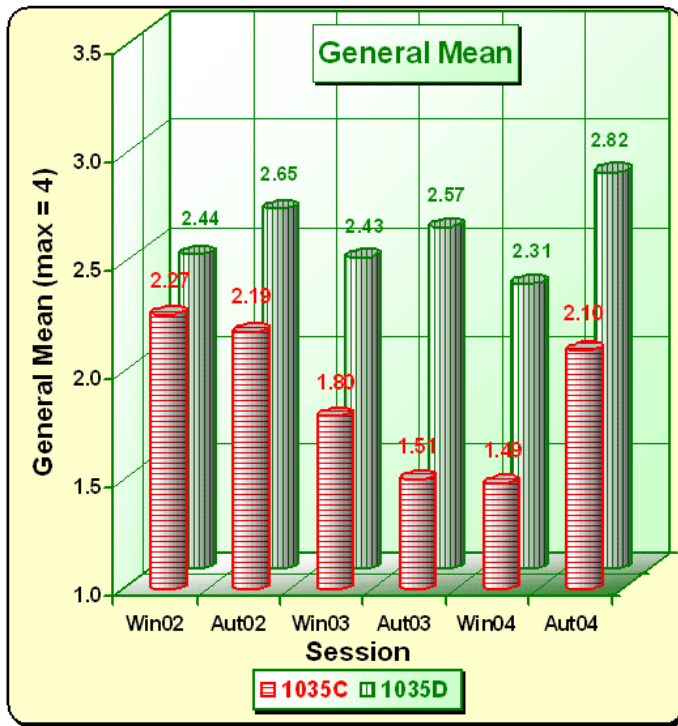


Figure 4: Evolution of the general mean for the ING1035 course during the six consecutive semesters.

From FIGURES 2 and 3, it can be concluded that the distribution of the grades (A, B, C, D, F) is less skewed in the “self-directed learning” version than in the “classic” version of the course: the peak of the histogram is centered at grade B for the 1035D version compared to grade C for the 1035C version. These results clearly reveal that the students enrolled in the “self-directed learning” version obtain generally higher final grades than those obtained by the students enrolled in the “classic” version. To illustrate this statement, consider the percentage of the students who have obtained A or A\* grades: this percentage is equal to 16.3 % for SL students while it drops to 8.2 % in the “classic” version of the course. Among other indices is the percentage of students completing the course with a D or D+ grade: this percentage is equal to 13.9 % for the “self-directed learning” version and increases to 19.2 % for the “classic” version. Finally, it must be pointed out that the percentage of students who have failed the course (grade F) is much lower in the “self-learning” version (6.5 %) than in the “classic” one (17.2 %). Two last indices are the percentages of students who have officially withdrawn (grade R) or “dropped-out” (grade F\*) from the course: these percentages are always lower in the “self-directed learning” version than in the “classic” one. Consequently, it is obvious that the general mean obtained by the students who have chosen the “self-directed learning” version is always higher than that of the students enrolled in the “classic” version (see Fig. 4).

<sup>2</sup> F = 0, D = 1, D+ = 1.5, C = 2, C+ = 2.5, B = 3, B+ = 3.5, A = 4, A\* = 4.5

#### 4. Analysis and discussion

In an attempt to identify the factors which could explain the marked difference for the student's success in the two versions of the course, we have performed a deeper analysis by selecting some possible factors that may be invoked. This statistical analysis was mostly done with Statistica. The definition of these factors and their expected influence are given in TABLE 2. Since, at the time of writing this paper, the complete data were not yet available in the general database of student's records, this analysis was essentially performed on the data compiled during the five first semesters (winter 2002 to winter 2004).

Table 2: Possible factors and their expected influence

Factor	Definition	Expected influence or effect
GPA (max. = 4)	General Point Average of a student who has completed or failed the ING1035 course at the time of extraction of the data from the general database (May 2004). This GPA is based on the engineering courses already completed by the students at Ecole Polytechnique.	It can be assumed that the higher the GPA of a student, the higher will be the final grade obtained in the ING1035 course. The GPA is an indicator of the strength of a student.
"Cote R" (max. = 50)	In the education system of the Province of Québec, the students have to follow a two year program of pre-university level in CEGEP after completing their secondary school and before entering the university. At the end of these two years, they receive a "Cote R" which summarises their level at CEGEP.	Like the GPA, the "Cote R" can be considered as an indicator of the intrinsic strength of a student. In Québec, the admission of a student in university programs with restricted access (e.g., medicine) is mostly based on his (her) "Cote R".
Pre-test (max = 60)	When a student is admitted in an engineering program at Ecole Polytechnique, he is invited to pass a test in order to evaluate his level in mathematics. Since this test is not compulsory, it is not written by all the students entering at Polytechnique.	As the "GPA" or the "Cote R", the result at the pre-test on mathematics is generally recognised as a good indicator of the strength of a student.
Mark at the common final exam (max. = 35)	The mark obtained by the student at the final common exam dealing with the compulsory units (1 to 7).	Since the compulsory units (1 to 7) are evaluated by the common final exam in both versions of the course, this factor may be of some help to evaluate the degree of retention of a student.
Quiz (max. = 20)	The averaged mark obtained by the students at the quizzes (2 written quizzes for version 1035C and 10 computerised quizzes for version 1035D).	This variable may reveal the degree of constancy of the efforts put by the student in the course during all the semester.

Since the numerical scale associated to a given factor presented in TABLE 2 (column 1) is different for each factor, the absolute value of a given factor was normalised by using a relative scale varying from 0 to 100 % when necessary.

As already shown in Fig. 4, the “self-directed learning” students (hereafter named SL students) obtain better marks in the course than the “conventionally taught” students (hereafter named CT students). This difference in performance is clearly confirmed by the t-Student test (presented in TABLE 3) and is confirmed by a Chi-square test.

Table 3: Statistical analysis of the final marks obtained by the students during five semesters. (t-Student test)

Mean 1035C	Mean 1035D	t-value	df	p-value	Sample size 1035C	Sample size 1035D
1.7997	2.3931	-9.0839	2139	0.00000	1575	566

An analysis of covariance (ANCOVA) was done with Statistica by considering the two main factors, which are assumed to evaluate the intrinsic strength of a student, namely his “GPA” and his “Cote R”. Results of this analysis are summarised in TABLE 4 and FIGURES 5 and 6.

Table 4: Analysis of covariance (ANCOVA) for the factors “GPA” and “Cote R”

	Degree of freedom	Sum of square	Mean square	F ratio	p-value
<b>Intercept</b>	1	50.06	50.06	61.63	0.000000
<b>GPA</b>	1	592.41	592.41	729.36	<b>0.000000</b>
<b>Cote R</b>	1	23.91	23.91	29.44	<b>0.000000</b>
<b>Final Mark</b>	1	74.91	74.91	92.22	<b>0.000000</b>
<b>Error</b>	1340	1088.40	0.81		
<b>Total</b>	1343	2329.29			



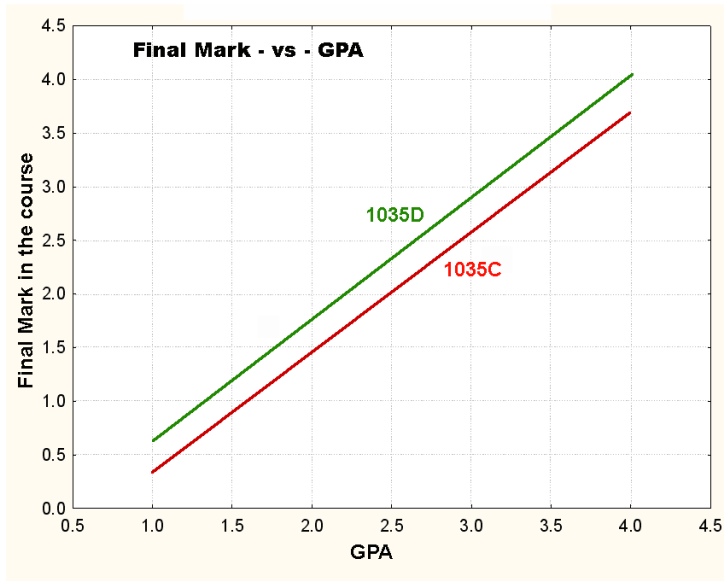


Figure 5: Influence of “GPA” on the final mark obtained in the course

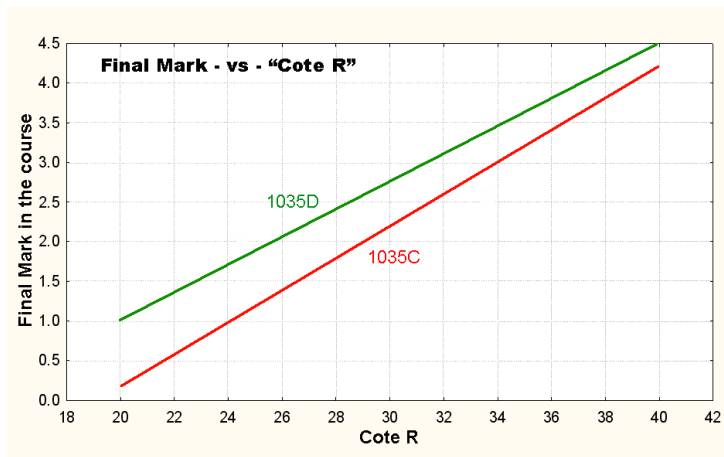


Figure 6: Influence of “Cote R” on the final mark obtained in the course

From the results shown in TABLE 4 and FIGURES 5 and 6, it is obvious that the higher the student’s strength (as “measured” by his GPA or his Cote R), the better his final mark in the course, a conclusion which is not very surprising! Since the students are free to choose what version of the course they want to follow, FIGURES 5 and 6 might also suggest that the “best” students feel more self-confident and preferably choose the “self-directed learning” version 1035D, while the students choosing the “classic” version 1035C prefer to be taught by a conventional method. However, the fact that the two curves in Fig. 5 and 6 are clearly separated strongly suggests that the strength of the students is not the main factor explaining the clear difference in their success according the version of the course they have chosen (see Fig. 4). To support this statement, an analysis of the predicted final mark which would be obtained by the students in the course, was done with Statistica with ignoring the influence of “GPA” and “Cote R”. In fact, this analysis assumes that all the students, whatever the version they choose, have the same intrinsic strength (same GPA and Cote R). Results of this analysis are shown in FIGURE 7

and clearly confirm that the strength of the students is not the main factor explaining the better results obtained in the “self-directed learning” version 1035D.

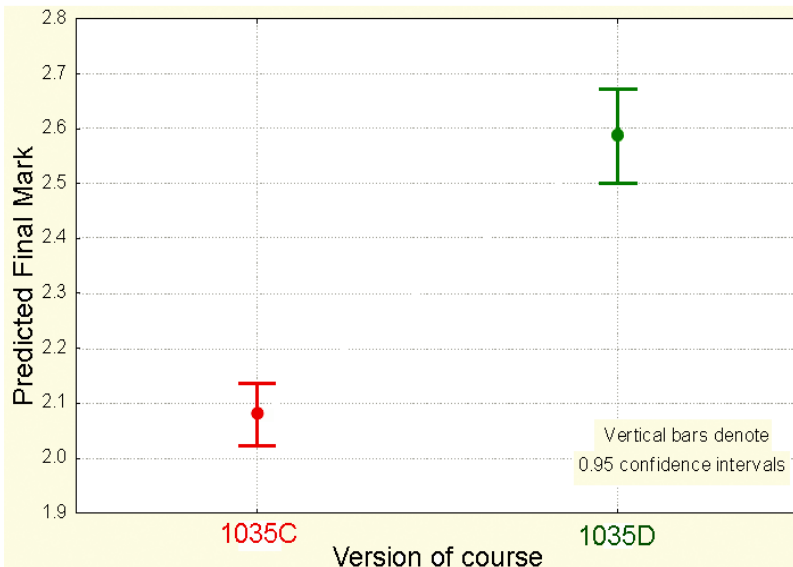


Figure 7: Predicted final average mark according the chosen version of the course if the influence of “GPA” and “Cote R” factors are excluded.

At this point of the analysis, one can conclude that the intrinsic strength of a student has a statistically significant effect on his result in the course 1035; however, this factor cannot solely explain the marked difference between the two versions of the course (Fig. 4). Among the factors presented in TABLE 2, it remains the average mark obtained at the common part of the final exam and the average mark obtained in quizzes. FIGURE 8 shows the evolution of the average mark obtained by the students at the common part of the final exam during five semesters.

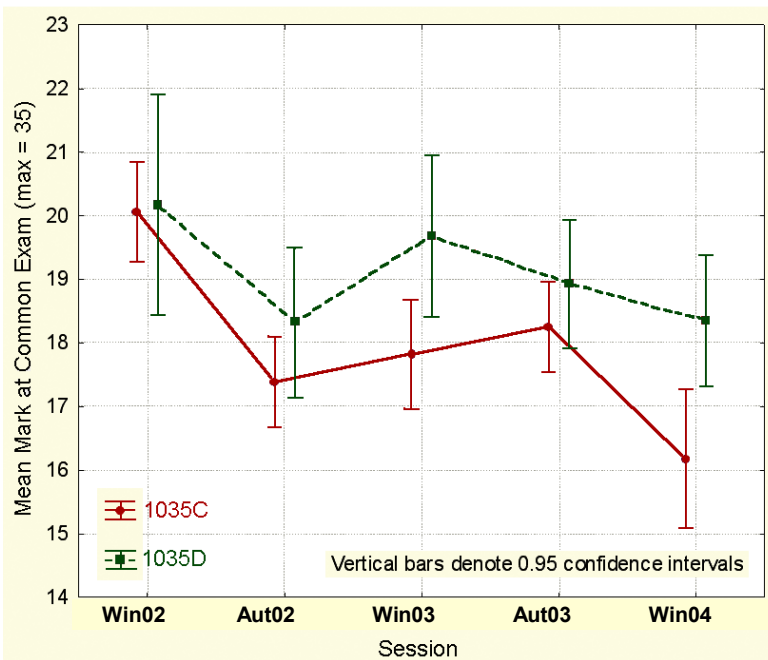


Figure 8: Evolution of the average mark obtained at the common final exam according to the version of the course

Once again, the SL students (version 1035D) perform better during the final common exam than the CT students (version 1035C) and this difference is statistically significant. Since the common part of the final exam covers all the topics treated in the compulsory units 1 to 7, this result suggest that the degree of retention demonstrated by the SL students is probably higher than that of the CT students.

Finally, the performance of the students during the quizzes is shown in FIGURE 9.

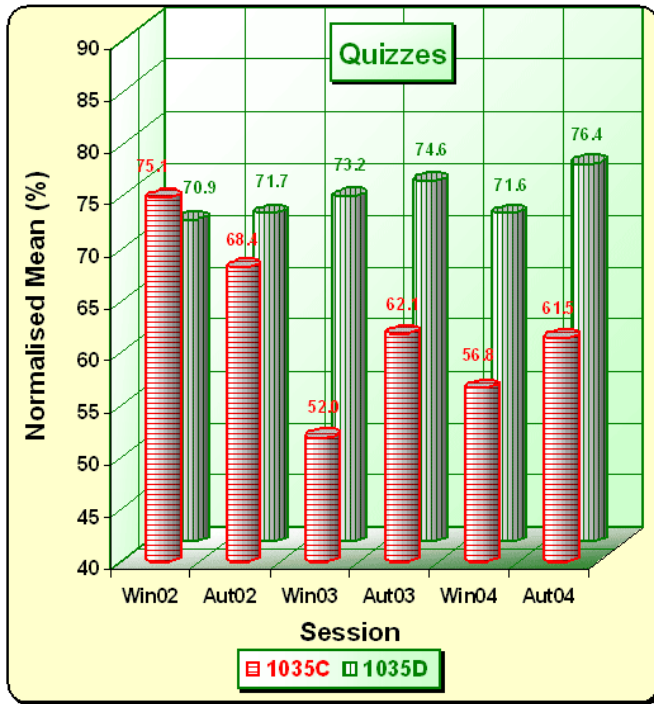


Figure 9: Normalised mean obtained by the students at quizzes according the version of the course.

From this figure, it can be easily concluded that the SL students performed better in quizzes than the CT students did. This difference in the student’s performance is lower for the first two semesters (winter 2002 and autumn 2002) most probably because the percentage of students who have chosen the 1035D version was lower at that time (see Fig. 1).

In order to sum up the potential influence of the factors, which may explain the clear difference in student’s success according to the version of the course they have chosen, FIGURE 10 summarises the effects of all the normalised factors presented in TABLE 2 and which can be invoked in order to explain this difference. The absolute numerical values of these factors are given in TABLE 5 with the associated standard deviation.

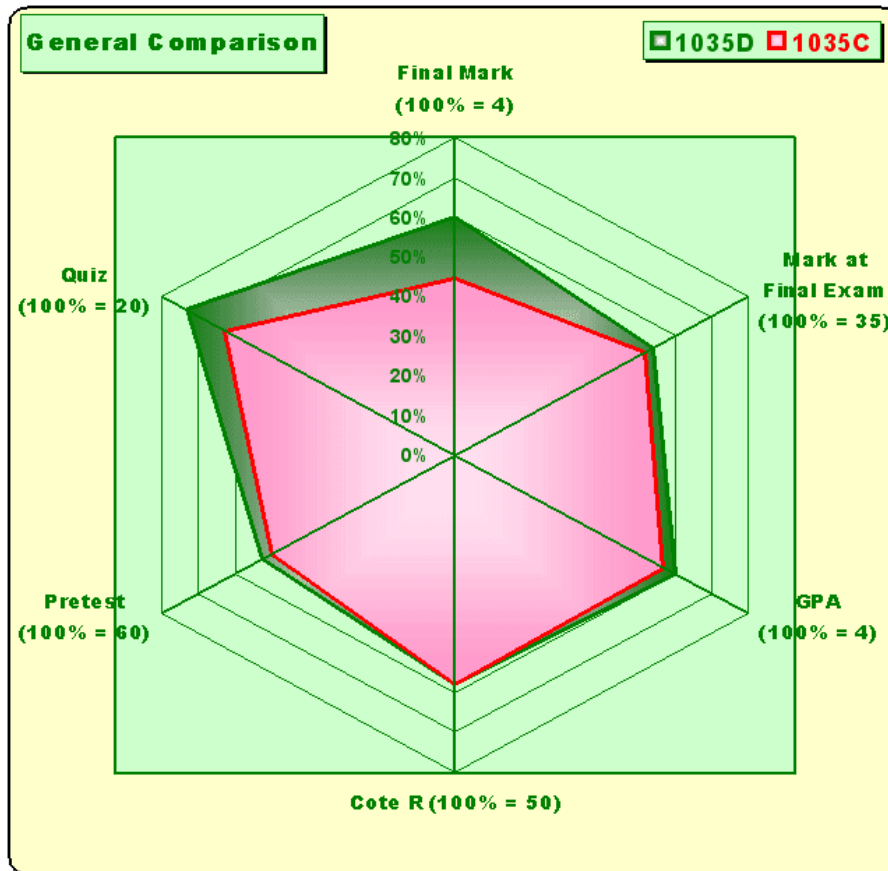


Figure 10: Summary of the effects of the potential factors on the student’s success according to the two versions of the course. All the factors have been normalised on a relative scale (0 to 100% of their absolute maximum).

Table 5: Absolute numerical values of the factors shown in Figure 10 prior to their normalisation

		Final Mark	Mark at the Exam	Quizzes	GPA	Cote R	Pre-test
1035C	Mean	1.79	18.12	62.67	2.28	28.90	29.97
	Std. Dev.	1.34	6.46	NA	0.87	3.31	10.17
1035D	Mean	2.40	18.97	73.06	2.41	28.95	31.40
	Std. Dev.	1.32	6.31	NA	0.79	3.65	9.71

Compared to the CT students (1035C), the SL students (1035D) have generally a slightly higher “GPA” and demonstrate a better performance at the “Pre-test” and at the final common exam of the ING1035 course. However their averaged “Cote R“ is almost the same than that of CT students. Consequently, even if these slight differences are statistically significant due to the large number of cases studied, these four factors (GPA, Cote R, Pre-test, Mark at the final exam) cannot solely explain the marked difference in the final mark for the course. This conclusion was already pointed out when we have commented the FIGURES 5 and 6.

**Thus, the only remaining factor which appears to be the most preponderant is the performance of the students at the quizzes.** Even if the quizzes have a different form according to the version of the course (classic written quizzes in 1035C and computerized quizzes in 1035D), it must be recalled that the level of difficulty of the quizzes is the same, since the same kind of exercises are proposed in both types of quizzes.

The question now is to explain why the SL students perform better in quizzes than the CL students do. Firstly, we recall that both types of students have the same didactic material at their disposal. One may argue that the SL students make larger use of the computer-based didactic tools (CD-Rom associated with the reference manual; interactive exercisers, videos and forum on the Website). From the evaluation of the course made by the students at the end of any semester, this argument is partially supported, since the SL students report using quite frequently these tools for understanding the topics, even if the reference manual remains the most essential tool of the course. As an indication of the use of the computer-based tools, the number of questions posted on the forum of the website is significantly higher in the 1035D version than that number in the 1035C version. Several studies compiled in some meta-analysis<sup>2, 3, 4</sup> have shown that computer-based instruction has a positive effect on the performance achieved by the students. However, we are not fully convinced that the computer-based tools have a positive effect on students’ success for the following reasons:

- The didactic material is absolutely the same for the two versions of the course. In case of a positive effect of the computer-based tools on students’ achievement, this effect should also be reflected on the CT students.
- The fact that the SL students post more questions on the forum of the website is the trivial consequence that these students never meet face-to-face a professor or a lecturer in a classroom, where questions are often asked by the CT students.
- If the SL students have more intensively used the computer-based tools with a positive effect on their performance, this effect should also have been present when these students have passed the final exam. Consequently the difference between the mark obtained by SL students and that of the CT students at this common exam should have been larger than the one presented in TABLE 5.

The most important factor contributing to the greater success of the SL students is their achievement in the quizzes (Fig. 10 and TABLE 5). In our opinion, the fact that the physical form of quizzes differs from one version to the other (written document in 1035C and computer-based quiz in 1035D) should not have a significant effect, since the degree of difficulty of the quizzes is the same for each version. One may also argue that the total time spent by the students for passing their quizzes during the semester is higher in 1035D version (10x60 min = 600 min) than in the 1035C version (2x105 min = 210 min), giving an apparent advantage to the SL students.

This argument is easily refuted since the number of exercises included in a quiz is adjusted according to the duration of the quiz and the topics covered by the quiz. For example, the topics covered by the exercises in a one hour quiz of 1035D are related to a single unit (lesson) of the course and the students have generally to solve three or four exercises and to answer up to five or six “true-false” or multiple choice questions. At the opposite, the topics covered by a quiz of the 1035C version are related to three or four units (lessons) of the course (see TABLE 1) and no more than two exercises related to a single unit are included in this quiz.

We are left with **the hypothesis that the SL students are probably more self-confident, more autonomous, more responsible and better organized than the CT students are**. As cited by Grow <sup>5</sup>, Candy <sup>6</sup> has proposed that the term “self-directed learning” has three meanings: autonomy as a personal quality; autodidaxy as learning outside formal instruction; and learner-control as (along with teacher-control) an essential consideration of formal instruction. In those terms, the SL students should have a higher degree of choice and a better control within an instructional situation. According to Grow’s classification <sup>5</sup> of the stages of learners, the SL students should be most probably at stage 2 (Interested) or stage 3 (Involved). It is interesting to note that, when they are asked to cite the reason(s) for which they have chosen the 1035D version during the evaluation of the course, many SL students invoke the freedom to organize their learning activities with this instructional mode. Another noticeable point is the fact that the “face-to-face” consultations with the tutors are not very popular and the object of the consultation made by the SL students is mainly for contesting the automatic correction of the computer-delivered quizzes. According to the testimony of the tutors, pretty rare are the SL students who consult for questions related to a better understanding of the topics which they have to learn and to master.

Furthermore, the schedule of evaluation in the 1035D version probably enhances the autonomy and strengthens the responsibility of the SL students, since they have to pass approximately one computerised quiz every week during the semester. Even if a quiz is accessible during 3 weeks, this schedule of evaluation forces the students to be more rigorous with their agenda and to work more constantly and more regularly. Interestingly, the best SL students who obtain a final A\* grade at the course, pass generally a quiz during the first two or three days when this quiz is made available in the computer lab, while the weaker SL students (final grade D or F) wait up until the last two days of availability for passing a quiz.

At the opposite, the CT students are probably learners at Stage 1 (Dependent) according to Grow’s classification <sup>5</sup>. They prefer the quiet “face-to-face” situation with a professor or a lecturer in the classroom where their attitude is often passive. They need to be directed by a teacher. Their schedule of evaluation (two quizzes during the semester at an interval of four to five weeks) tends probably to encourage their procrastination. They generally wait until two or three days preceding a quiz for reviewing in a crash manner the topics, which covers three or four units (lessons); during the semester, their rate of activities follows a saw teeth pattern and they are often overflowed by urgent tasks. The consequence of such an attitude is a poor preparation to the quizzes with the concomitant worst results.

## 5. Conclusions

Based on observations made during six semesters, the comparison of students' success in two versions of the same course (ING1035) has revealed some interesting facts. The first version (1035C) is based on a conventional mode of learning where the CT students are taught 3 h/week by a professor or a lecturer in a classroom and are evaluated through two conventional quizzes and a final exam. In the second version (1035D), the SL students are invited to learn by themselves without any "face-to-face" with a professor. If they wish, they may consult tutors or post questions on the forum of the website. They are evaluated more continuously (approximately one computerized mini-quiz every week of the semester). It must be stressed that the two categories of students have the same didactic material at their disposal and that the content and the objectives of the course are the same as proved by a final common written exam. One last point: the students are free to choose the version of the course which they want to follow. From the data analysis of the grades and marks obtained by the students and from the database of students' records, we may conclude that:

- The histogram of the final grades obtained by the SL students is less skewed than that of the CT students. The peak of this histogram is centered around B grade for SL students while this peak appears around C grade for the CT students. The percentage of SL students completing the course with an A or A\* grade is notably higher for SL students while the percentage of students who failed the course (F grade) is much higher for the CT category.
- Factors which could explain this difference in the students' success have been considered, namely three factors supposed to evaluate the intrinsic "strength" of a student: his GPA, his Cote R and the grade obtained in a pre-test of mathematics. Even if these factors appear to be statistically slightly higher for SL students, they do not explain the difference in the students' success.
- The performance of the SL students at the final common exam is slightly better and statistically significant than that of the CT students. However, this performance cannot explain the marked difference in the final grades.
- The main cause of the higher success of the SL students in the course is most probably their attitude toward their responsibility in the learning process. The SL students are generally more self-confident, more autonomous and better organized than the CT students are. These individual aptitudes are reinforced by the schedule of the quizzes which forces the SL students to learn on a more regular and constant basis resulting in better results for their quizzes.

## 6. Acknowledgements

We want to acknowledge Roger Martin, director of the Office of Academic Affairs, for his help in extracting all the information we needed from the general database of students' records. Fruitful discussions on the interpretation of the experimental results have also been conducted with Richard Prigent, director of the Center of Teaching and Learning.

## 7. References

- [1] BAÏLON Jean-Paul et DORLOT Jean-Marie: "*Des Matériaux*", 3<sup>rd</sup> édition, Presses Internationales Polytechnique, Montréal (Canada), 2000, 736 pages, with an interactive CD-Rom.
- [2] COHEN Peter A. and DACANY Lakshmi S., *Computer-based instruction and health profession, Evaluation and the Health Profession*, vol.15, September 1992, pp. 259-281.
- [3] LESH Steven G. and RAMPP Lary C., *Effectiveness of Computer-Based Educational Technology in Distance Learning: A Review of the Literature*, U.S. Department of Education, Office of Education Research and Improvement, 53 p., ED 440 628, IR 019 992, 2000.
- [4] FREAR Valerie and HIRSHBUHL John J., *Does interactive multimedia promote achievement and higher thinking skills for today's science students?*, British Journal of Educational technology, Vol. 30, n° 4, pp. 323-329, 1999.
- [5] GROW Gerald, *Teaching Learners to be Self-Directed*, Adult Education Quarterly, vol. 41, n° 3, Spring 1991, pp. 125-149.
- [6] CANDY Philip C., *Reframing research into "self-direction": A constructivist perspective*. Doctoral Dissertation, University of British Columbia. Ottawa: National Library of Canada, Canadian Theses, Microfiche: 0-315-40011-0, 1987.

## 8. Biographies

Jean-Paul BAÏLON is full professor of materials science in the dept. of Mechanical Eng. at Ecole Polytechnique of Montréal. He is a co-author of a book entitled "*Des Matériaux*" (see ref. [1]) and, during his career of teacher, he has explored several approaches for improving the efficiency of teaching (lap dissolve slide shows, videotapes, interactive CD-Rom, web sites, Flash applets,...). His main fields of research cover the relationships between the microstructure of materials and their mechanical properties, particularly in fatigue and rupture.

Bernard CLÉMENT his full professor of mathematics in the dept. of Mathematics and Industrial Engineering. Statistics, statistical methods and quality control are his main fields of activities, either in teaching or research.

Pierre LAFLEUR was recently appointed dean of studies at Ecole Polytechnique de Montréal. Previously, he was full professor in the dept. of Chemical Eng. in the same institution and his fields of interest were the processing of polymeric materials either in teaching or research.