Students' e-skills, organizational change and diversity of learning process: Evidence from French universities in 2010

Adel BEN YOUSSEF[1]
(University of Nice Sophia Antipolis & GREDEG-CNRS)
adel.ben-youssef@unice.fr

Mounir DAHMANI
(Ecole Polytechnique of Paris & PREG-CRG)
mounir.dahmani@polytechnique.edu

Nessrine OMRANI
(University of Paris Sud & ADIS)
nessrine.omrani@u-psud.fr

Abstract

Driven by ICT, universities are changing in depth the nature and forms of learning processes, which are supposed to prepare students to a better entry into the labor market. In this paper, we focus on the evolution of students' ICT use in such an institution characterized by organizational changes and analyze the determinants of students' e-skills using a 2010 dataset on French university students. We show that students' involvement in the use of ICT increases their e-skills. ICT learning by doing and ICT learning by using also increase some categories of students' e-skills. In addition, collaborative and cooperative learning are positively associated with students' advanced e-skills.

Key words: Students, ICT, E-skills, Multinomial logit model, New Organizational Practices, labor market.

JEL: O33, J24

[1] Corresponding author

1. INTRODUCTION

Advances in Information and Communication Technologies (ICT) have dramatically transformed the work place during the past two decades. The basic requirements of education for future employment have changed since knowledge became the most critical resource for social and economic development ([Hakkarainen et al.2000]). Ability to use computer and Internet effectively, a qualified education, and communication skills can be seen as prerequisites for white-collar jobs.

Universities have invested a lot in ICT equipment during the past two decades ([OECD2006]). ICT use is supposed to improve the educational output and, thus, the quality of higher education. Many researchers have shown that ICT use leads to an improved academic performance (measured by the success in exams and achievements, [Hoskins and van Hooff2005]; [van Dijk2006]; [Rivkin et al.2005]; [Su2008]; [Tuparovaa and Tuparova2010]). In addition, it has been claimed that using ICT use in Higher Education facilitates e-skills' acquisition by students. In sum, ICT use improves the students' prospects in the labor market. For the U.S., it has been reported that, since students later join the labor force, Internet use at universities has led to an increase of ICT use in the whole US economy ([Goldfarb2006]). In the European Union, a strategy was put in place to improve the e-skills of the labor force ([Fonstad and Lanvin2009]; [Kolding and Kroa2007]). While an extensive literature has discussed the academic performances of students associated to ICT usage ([Angrist and Lavy2002]; [Banerjee et al.2007]; [Lundberg et al.2008]; [Machin et al.2007]), the effect on skills acquisition appears to be underexplored.

Understanding successful use of ICT in higher education and its implications is of high practical relevance. It is important for long-term strategic pedagogical planning of technology implementation in education ([Jonassen et al.2005]; [Nicol and MacLeod2005]) as it affects the engagement of students in active learning and problem solving through ICT ([Barak et al.2006]).

Following such recommendations suggests organizational changes within universities. With respect to the debate about the productivity paradox,[2] performance associated to ICT usage depends strongly on the adoption of *New Organizational Practices* (NOP) ([Greenan and Mairesse2004]; [Greenan and Walkowiak2006]). During the last decade, many firms have experienced a reorganization of their workplace. New work practices have been adopted such as job rotation, delayering, self-directed work-team, just-in-time and total quality management ([Askenazy et al.2001]). [Ichniowski et al.1997]; [Black and Lynch2001b]; [Caroli and Van Reenen2001] find a positive impact of new work practices on productivity especially in connection with information technologies.[3] According to [Arvanitis and Loukis2009], ICT, new organizational practices and human capital can contribute to firm efficiency and performance.

As exemplified above, empirical research is mostly devoted to industry, few empirical works analyze the adoption of new organizational practices at universities and their impacts on the learning processes and the outputs of higher education. In the European Union, the [SEUSISS

[2] For detailed explanation of the productivity paradox see the paper of [Triplett1999].

[3] [Black and Lynch2001a]; [Askenazy and Gianella2000] and [Bresnahan et al.2002] underline the importance of introducing clusters of complementary practices. New work practices are biased against unskilled labor leading to an upskilling of firms' occupational structure ([Askenazy2000]; [Greenan1996]; [Caroli and Van Reenen2001]).

Project Final Report2003] suggests that university students learn, develop or 'pick up' their ICT skills from a variety of formal and informal sources. This includes formal training sessions at school or college and informal tuition from friends, family or peers as well as self-teaching with the help of user manuals.

The aim of this paper is to analyze whether and how NOP adopted by the French universities led to an improvement of students' e-skills in 2010. We show whether and how organizational changes allow students to be better prepared to face labor market requirement and to meet the organizational requirements within the firms. Our argument is that e-skills' acquisition and accumulation require a significant organizational change in the higher education institutions (collaboration, innovativeness, teacher-student interaction outside the class…), a diversity of learning processes (learning by doing, learning by using, and learning by failing), and an important investment by students (measured by time spent surfing on the Internet, and ICT trainings). For this purpose, we use a questionnaire database collected in France in 2010 encompassing 1462 students from three French universities.

The structure of the paper is the following: Section 2 discusses the research background and the related literature. Section 3 introduces the data. Section 4 contains the econometric methodology and the variables. Section four presents the results and discusses the main findings. Section 5 concludes.

2. RESEARCH BACKGROUND: ICT, NOP AND E-SKILLS

This section is dedicated to the discussion of the research background. Firstly, we clarify the debate about E-competences and our chosen definition. Secondly, we present the different means by which organizational changes within the universities impact their e-skills. Three complementary channels of organizational change are discussed: behavioral change of students induced by organizational change, strategies for diversifying the learning mechanisms and collaborative learning.

2.1. E-skills

[Steyaert2002] provides a classification of e-skills. He distinguishes between instrumental e-skills, i.e., the operational manipulation of technology, structural e-skills, i.e., the structure in which information is contained, and strategic e-skills, i.e., the basic readiness to pro-actively look for information, information-based decision-making and scanning of the environment for relevant information.

Concerning structure, it is not clear whether these skills are only a prospect understanding of ICT tools or, in addition, include the identification of the information. [van Dijk2005] modifies Steyeart's definition. He distinguishes between operational, information, and strategic e-skills. Operational skills are the skills to operate computer and network hardware and software and can be seen as equivalent to instrumental e-skills. Information skills are the skills to search, select, and process information in computer and network sources. This skill category is subdivided into formal information skills (the ability to understand and to handle the formal characteristics of a computer and a computer network such as file structures, menu structures, and hyperlinks) and substantial information skills (the ability to find, select, process, and evaluate information in specific sources of computers and networks according to specific questions and needs). And finally strategic e-skills are the capacities to use these

sources as the means for specific goals and for the general goal of improving one's position in society, which corresponds to Steyeart's classification.

[van Deursen and van Dijk2010], instead of considering formal information skills and substantial information skills as subcategories of information skills, introduce formal skills for the former and information skills for the latter as two separate categories. While formal skills strongly relate to the characteristics of digital technology, information skills together with strategic skills, relate to the content provided by ICT tools. They distinguish between (1) operational skills as the skills to operate digital media, (2) formal skills as the skills to handle the structures of digital media, and (3) information skills as the skills to locate information in digital media and strategic skills as the skills to employ the information contained in digital media towards personal and professional development.

We adopt in our paper the [van Deursen and van Dijk2010]'s definition of e-skills. Students' e-skills are divided into four categories starting from the basic e-skills (structural e-skills) to the more advanced ones (strategic e-skills), which are based on collaborative work. Students who only have structural e-skills tend to be the later adopters of ICT. They only have skills to operate a computer. They do not use ICT intensively and do not use them for collaborative work. Then, regarding formal e-skills, students in this category, in addition to structural e-skills, use some basic Internet applications. Concerning students who have the third category of e-skills (information e-skills) they use ICT as tools for learning purposes in addition to the two first categories. Finally, strategic e-skills, which are the most advanced, include students who are early adopters of ICT. These students use ICT intensively in order to collaborate with others.

1.2. How do organizational changes within university impact students' e-skills?

The central question of our article is to look how NOP enhance the development of student's e-skills. Our basic idea is that for effective ICT use, universities have to explore new forms of learning and students have to develop new attitudes. These forms of learning and attitudes are not developed by the classical way of teaching within universities. The use of ICT combined with the classical way of learning does not fully exploit the potential of students' ICT use. Changes in the organization of the classrooms and the way of teaching improve the performance of those students who acquire more e-competencies. According to [Arvanitis and Loukis2009], the use of computer technology can lead to productivity gains through improved communication possibilities among employees.

Three main changes can be observed when the university teaching is reorganized to adjust for the new possibilities of ICT. First, the student-centered model of learning implies that students are more involved in all the tasks of learning. They are spending more time on learning (autonomous, more implicated) and follow more courses related to ICT in order to improve his skills. The second change is related to the diversity of learning mechanisms. While learning-by-studying is the most used form in the classical way of learning, the use of ICT allows more learning mechanisms to be used namely learning-by-doing, learning-before-doing, learning-by-using, learning-from-competitors (other students). This diversity of the forms of learning is due to changes in the organization of the courses and the organization of the whole study program. The third and last change is related to collaborative learning. ICT are also collaborative technologies and enable a better students' collaboration at the universities. For this purpose, organizational changes are needed that allow for more "cooperation" and "collaboration" between students themselves and between students and teachers.

(1) Students' behavioral change: autonomy, problem solving and implication

ICT use at universities enables them to switch from a teacher-centered pedagogy to a learner-centered one ([Keengwe et al.2009]; [Saulnier et al.2008]). This requires an educational organization that is based on an active way of learning with different activities, which are determined by learners in small groups and where pace is determined by learners individually. By contrast, in the classical way of teaching, there is little variation in activities, they are prescribed by teacher in a whole class instruction, and pace is determined by the program. [Barak et al.2006] state that engagement of students in active learning and problem solving through ICT is a key to pedagogically successful use of ICT.

More involvement of students by using these tools and improving ICT uses are a first step toward a better performance in terms of e-skills. Different learning strategies ought to be implemented in order to increase the autonomy and the involvement of the student in classroom interactions. A large part of the learning process becomes centered on interactions outside the classroom where the involvement of the student is central. These changes can be observed through the change of the students' behavior of the time spent on the Internet for pedagogical purposes and of the enrolment in more courses related to ICT.

These organizational changes are also observed in firms. These need more autonomous workers, with the ability to take initiatives and to be fully involved in their job. Part of their job is done outside the firm's premises and the workers' capabilities developed during their higher education can be used for their jobs. To summarize, the organizational changes within universities foster e-skill acquisition and prepares prospective workers for the NOP in firms ([Blass2005]; [Fernandez2007]). These changes tend to improve their employability and their future wages.

(2) Diversity of learning mechanisms instead of static learning: innovativeness, and technological absorptive capacity

"ICT has been transforming the way we communicate, the way we do business, the way we work, it is inevitable that it changes the way we learn" ([Zammit2004]). According to [Zammit2004], the learning process is changing. In the presence of ICT more mechanisms of learning are available, which students can choose from. According to [Pavitt1985]'s classification there are at least five kind of learning processes: learning-by-using, learning-by-doing, learning-from-competitors, learning-by-failing, and learning-by-studying. Universities are seeking to diversify the mechanisms of learning through the use of ICT. Many have implemented an organizational change in the organization of learning processes by developing more interactions between students and teachers and between students themselves.

The fact that students are exploring more mechanisms of learning may help them to develop their skills for more technological absorptive capacity. These skills are at the heart of the new organizational model of the firm today ([Caroli2001]). Firms are seeking workers who are able to learn and develop the capability to absorb new technologies and new knowledge and it appears to be important that during their higher education students develop these competencies.

(3) Collaborative and cooperative learning: Modularity, team work, work by project

ICT facilitates educational collaborations between individuals and groups of people. Such collaborations may take place locally or between people in separate geographical locations. Students may collaborate with peers in other schools, teachers may collaborate with their

peers, members of the local business community may serve as mentors to students, and so forth. According to [Thijs et al.2001], there is a move from a traditional pedagogic organization to an emerging pedagogic organization (in the information society) based on an active, collaborative (working on teams within heterogeneous groups where students support each others rather than individual work in heterogeneous groups where everyone works for himself), creative (productive learning rather than reproductive learning), integrative (between theory and practice and between different subjects and disciplines) and evaluative learning (towards a more diagnostic approach rather than summative and student directed rather than teacher-directed). ICT and organizational change within the university are complementary as they jointly allow more cooperative and collaborative learning.

The last decade has seen major changes in the French universities[4]. Firstly, universities became more autonomous.[5] They are in control for their own resources, setting their own strategies, and manage their own human resources. This major change implies that there is a change from a central hierarchical model of the university to a more dynamic and decentral model where competition between universities is becoming the rule. Universities then more autonomously chose their pedagogical strategies. Secondly, French universities are trying to consider pedagogy as one of the three components to evaluate their teachers/researchers.[6] The two other components are publication success and involvement in the institution by taking some responsibilities. This has lead some teachers to explore new pedagogical strategies. Thirdly, several initiatives were taken in order to reverse the tendency of high student dropout rates in the initial years at university. These initiatives have tried to use ICT, online tutoring, collaborative work, and work in small groups in order to improve the success and retention rate in initial years at university. These initiatives have tried to change the way courses are organized. Fourthly, several universities (especially in the field of economics and management) have invested in content production of e-learning programs. This strategy involved teachers, staff and students. Most of the French universities are currently trying to offer blended learning and to use some of the resources developed online for regular students attending class.

The fact that students are trained to be cooperative and collaborative is likely to give them a better prospect to successfully integrate in teams and to work by projects. These abilities are also important requirements in the professional world and, thus, critical success factors in the labor market. Improving these kinds of skills in higher education can thus be seen as important investments for the labor market. As alluded to above, these NOP are wide used within the firms nowadays. Several contributions have shown that the complementarities between the adoption of organizational change and adoption of ICT lead to better productivity of firms' performances. By acquiring these competencies students are better skilled and have more probability to have a job ([Hakkarainen et al.2000]).

[4] Many other changes have occurred and were not taken into account in our article. They have also contributed to redesign the organization of courses within French universities.

[5] The new organization of the French Universities is organized with the new law n° 2007-1199 (08/10/2007). According to this law universities are able to set their own policies without interference by the Ministry of Higher Education.

[6] Initially the evaluation was based upon publication. Higher Education Teachers were not « incited » to invest in pedagogy. Most of them have not followed any pedagogical training ([Ben Youssef and Hadhri2009])

3. DATA AND METHODOLOGY

This section presents the data used in this study. We elaborate on the sources of the dataset, their limitations, and how it was collected. Finally, we provide some descriptive statistics of the variables used in this study.

3.1. Data collection

The data were collected by a survey conducted in France in 2010[7]. The survey investigates the students' ICT adoption and use. We used the survey approach, instrumented via a face-to-face questionnaire data-gathering technique. The questionnaire includes four parts: the first concerns the characteristics of the student, the second explores the motivation of the student for study, the third seeks to assess the facilitating conditions, while the fourth seeks to account the diversity of ICT uses which students use.

A pilot study with a group of 20 students was undertaken in order to ensure the questions were adapted appropriately to the research context. The purpose was to find out potential problems and misunderstandings of instruction and question items. After the pilot test, some small adjustments were made. Finally, a total of 1522 students took part in the survey. In order to accomplish the research objectives and the econometric analysis of the data, it was necessary to exclude respondents that reported inconsistent responses and respondents who did not answer all the questions. After these adjustments the sample consists of 1464 observations.

3.2 Sample characteristics

The final sample contains 1464 students from three French universities: University of Paris Ouest - Nanterre la Défense, University of Paris-Sud and University of Nice Sophia-Antipolis. The descriptive statistics are summarized in Table 1. A fraction of 69.4% of surveyed students belong to the University of Paris-Sud 11, 21.2% to the University of Nice Sophia-Antipolis and 9.4% to the University of Paris-Ouest Nanterre La Défense. Around 40% of respondents carry out their first year of undergraduate degree studies, 36% their second year of undergraduate degree and 24% their third and final year of the undergraduate degree. More than 31% of the sample carries out professional activities in parallel with their studies. In our sample, 52.2% of all students are male and 47.8% female. Respondents' age is divided into various age groups. The age means of our sample is 21. The average age of female students is 20 while it is 21 for male (the average age of male and female students is more or less the same).

A majority of respondents (78%) reported that their institution has developed ICT student training programs for them. Around 68% of the respondents state that their university provides ICT training. Around 58% of the respondents claim to have followed an ICT tools use training. Only around 36% of the respondents reported that they had attended an ICT training program inside or outside their institution with the aim to use ICT effectively for learning purposes. Almost 89% of the respondents have a computer at home. Similarly, the vast majority of the respondents (80.5%) have a laptop. And almost all students have an Internet connection at home (96.2%). Most of the respondents spend between 1 and 5 hours per week using Internet for educational purpose, 20.1% use it for less than an hour per week,

[7] The Survey is the third edition of a questionnaire run initially for a European Project that aims to examine the economics of e-learning (www.elene-ee.net). The survey was conducted initially to explore the different levels of the digital divide ([Ben Youssef and Dahmani2008]).

14.8% between 6 and 9 hours, 5.3% from 10 to 14 hours and only 3.9% use it for more than 15 hours. Table 1 reports these sample statistics.

Table 1. Sample description

Variables N=1464	Distribution (%)	Standard deviation	Min	Max
Gender				
Female	47.7	0.4997	0	1
Male	52.3	0.4997	0	1
Age				
17 to 19	39.3	0.4885	0	1
20 to 21	36.7	0.4823	0	1
22 to 23	20.8	0.4063	0	1
24 and more	3.1	0.1745	0	1
University				
University of Paris-Sud	69.3	0.4616	0	1
University of Nice-Sophia Antipolis	21.2	0.4092	0	1
University of Paris 10	9.5	0.2932	0	1
Level of education				
First year of undergraduate degree	40.0	0.4901	0	1
Second year of undergraduate degree	36.1	0.4806	0	1
Third and final year of undergraduate degree	23.8	0.4262	0	1
Having a job while studying				
Not having a job while studying	67.0	0.4703	0	1
Having a job while studying	33.0	0.4703	0	1
Computer at home				
Not having a computer at home	11.1	0.3147	0	1
Having a computer at home	88.9	0.3147	0	1
Laptop				
Not having a laptop	19.5	0.3961	0	1
Having a laptop	80.5	0.3961	0	1
Internet connection at home				
Not having an Internet connection at home	3.8	0.0383	0	1
Having an Internet connection at home	96.2	0.9617	0	1
Providing ICT trainings by the university				
The university do not provide ICT training	32.0	0.4665	0	1
The university provides ICT training	68.0	0.4665	0	1
Following an ICT use training				
Not following an ICT use training	58.3	0.4933	0	1
Following an ICT use training	41.7	0.4933	0	1
Time spent on the Internet for educational purposes				
Less than one hour per week	20.1	0.4007	0	1
1 to 5 hours	55.9	0.4967	0	1
6 to 9 hours	14.8	0.3554	0	1
10 to 14 hours	5.3	0.2246	0	1
15 hours and more	3.9	0.1935	0	1

4. ECONOMETRIC MODEL

The objective of this study is to identify the determinants of students' e-skills. We assume that the probability that a student is in one of the four different categories of e-skills depends on his characteristics, his involvement to the use of ICT, the level of his ICT use, and the use of ICT tools for collaborative and cooperative purpose. Under this assumption of a discrete choice, the appropriate model is a multinomial logit,[8] shown in equation (2) below. This model determines if the relevant factors identified in the literature review (presented above) influence the probability of students to be in one of the four different e-skills categories. Let ESKILLS denote the i^{th} student's category of e-skills variable, which can then be observed as:

$$\text{ESKILLS} = \begin{cases} = 1 \text{ if student } i \text{ has operational e-skills} \\ = 2 \text{ if student } i \text{ has formal e-skills} \\ = 3 \text{ if student } i \text{ has information e-skills} \\ = 4 \text{ if student } i \text{ has strategic e-skills} \end{cases} \quad (1)$$

The multinomial logit model is then defined by the following equation[9].

$$\Pr ob\left(\text{ESKILLS} = m \middle| X_i\right) = \frac{\exp\left(\beta_m^{'} X_i\right)}{\sum_{j=1}^{4} \exp\left(\beta_j^{'} X_i\right)} \quad (2)$$

Where m = 1, 2, 3 or 4 and j = 1,…, m, ESKILLS denotes the observed outcome, β denotes a vector of coefficients, X is a vector consisting of ICT skills variables and other explanatory variables such as age, gender, university, level of education, other related ICT facilities, etc. The coefficients are then estimated by maximum likelihood.

When estimating a multinomial logit model it is required to choose a reference category with coefficients normalized to 0.[10] Due to the requirement of a reference group, the coefficients from other groups should be compared to this reference group. The reference group is then defined by the following equation.

$$\Pr ob\left(\text{ESKILLS} = 0 \middle| X_i\right) = \frac{1}{\sum_{j=1}^{4} \exp\left(\beta_j^{'} Y_i\right)} \quad (3)$$

5. VARIABLES

This section presents the variables used in the econometric analysis. Two sets of variables are defined, dependent variable, namely, e-skills level and independent variables, namely determinants of students' e-skills accumulation. The first set of variables is obtained through a classification procedure. They identify and characterize the different levels of students' e-skills. The second set of variables contains the explanatory variables related to the

[8] Please note that we also tested our adoption equation through ordered logit and ordered probit models. The results achieved were very similar, which confirms the robustness of the equation. Nevertheless, the multinomial logit model was preferred insofar as it is difficult to interpret the ESKILLS_3 and ESKILLS_4 classes as ordered in terms of categories of e-skills.

[9] See e.g. [Maddala1993] or [Franses and Paap2001].

[10] In this study the reference category is 1, i.e. operational e-skills.

characteristics of the students, their involvement to the use of ICT, the level of their ICT use, and the use of ICT tools for collaborative and cooperative purpose.

5.1. Dependent variable: Students' e-skills

The participants in our survey were asked to rate their level of skills and the frequency with which they use nineteen ICT applications. These ICT variables are specified through five-point Likert scale responses, ranging from value "1" for students who have neither adopted, nor tested these technologies to value "5" for the earliest adopters and those who use them intensively.

To characterize the different modes of ICT usages and skills, a Principal Component Analysis (PCA) was conducted with the nineteen variables. The PCA resulted in four factors with an eigenvalue larger than 1 (see Table 2). The total variance explained by these factors is 53.33%. Generally in social sciences this rate is considered as satisfactory ([Hair et al.2006]). We defined the factors as following:

- Factor 1: The generic use of computer
- Factor 2: The generic use of Internet
- Factor 3: The use of ICT for pedagogic purposes
- Factor 4: The use of ICT for collaborative work purposes

Table 2. Results of the Principal Component Analysis for the different modes of ICT usages and skills

	Factor			
	F1	**F2**	**F3**	**F4**
Proficiency in presentation software	0.821			
Proficiency in word processing software	0.802			
Proficiency in spreadsheet software	0.786			
Proficiency in discipline-specific software	0.559			
Proficiency in device installation	0.528			
Proficiency in social networks applications		0.769		
Proficiency in forum and chat applications		0.731		
Proficiency in messaging software		0.656		
Proficiency in search engine		0.528		
Encyclopedias use as support of courses			0.735	
Databases use as support of course			0.706	
Forums use as support of course			0.563	
Team work using ICT				0.806
Internet use as a tool for setting goals				0.777
Technology use to facilitate working with colleagues				0.736
Task work using Internet				0.717
Parallel work on multiple projects using ICT				0.635
Internet use for research projects				0.591
Internet use to facilitate information flow				0.498

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
Rotation converged in 5iterations.

In order to test the reliability of the summated scale, the internal consistency reliability was verified by Cronbach's alpha. The coefficient varies from 0 to 1, and a value of 0.6 or less generally indicates unsatisfactory internal consistency reliability ([Malhotra2009]). In social sciences, acceptable reliability estimates range from 0.7 to 0.8 ([Nunnally and Bernstein1994]). The results (documented in Table 3) reveal that the Cronbach's alpha values for each of the four dimensions were greater than 0.7 except for generic use of Internet dimension (0.67).

The Bartlett's Test of Sphericity shows that non-zero correlations exist at the significance level of 1%. The reduced set of variables meets the necessary threshold with a Kaiser-Meyer-Olkin measure of sampling adequacy value of 0.86. All of these findings provide evidence of the appropriateness of the sample for the principal components analysis.

Table 3. Reliability and goodness of fit of factors statistics for students' e-skills PCA

Factor	**Eigenvalue**	**Percent of variance**	**Cumulative percent of variance**	**Cronbach's alpha**
F1: The generic use of computer	4.919	25.89	25.89	0.77
F2: The generic use of Internet	2.57	13.528	39.418	0.67
F3: The use of ICT for pedagogic purposes	1.361	7.161	46.579	0.74
F4: The use of ICT for collaborative work purposes	1.284	6.759	53.339	0.85
KMO and Bartlett's Test				
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.			0.862	
Bartlett's Test of Sphericity		Approx. Chi-Square	8169.35	
		df	171	
		Sig.	0.000	

In order to identify the different levels of students' e-skills, we group the 1464 students using cluster analysis. Cluster analysis was conducted using Stata (version 11) software in order to explore options for grouping the different students' e-skills levels. The objective of cluster analysis is to find homogeneous groups and to maximize the difference between groups. Unlike most parametric statistical techniques, cluster analysis does not explicitly provide a clearly acceptable or unacceptable solution. [Bocquet and Brossard2007] and [Sharma1995] recommend that one should use different approaches, compare the results for consistency and use the method that results in an interpretable solution.

A non-hierarchical cluster analysis (ESKILLS) based on *k-means* methodology is then carried out based on the scores revealed by the principal factor analysis. In order to determine the final number of clusters, we use three usual criteria:

- The statistical accuracy of the classification measured by the ratio of within-cluster and between-clusters variances (Fisher's test);
- The number of students per cluster;
- The economic significance of the clusters identified.

According to these criteria, the version with four clusters of e-skills is adopted. In order to interpret these four clusters, we calculate the mean of each ICT indicator in each cluster.

Table 4. Interpretation of ESKILLS clusters

ESKILLS	Mean			
	GENCOMP	GENINT	ICTPED	ICTCOLL
No. 1= Operational e-skills (ESKILLS_1) (N=380)	**2.56**	2.31	2.06	2.41
No. 2= Formal e-skills (ESKILLS_2) (N=476)	**3.06**	**3.56**	2.22	2.96
No. 3= Information e-skills (ESKILLS_3) (N=356)	**2.99**	**3.14**	**3.37**	3.70
No. 4= Strategic e-skills (ESKILLS_4) (N=252)	**3.93**	**4.50**	**3.12**	**3.91**

Note: The mean is in bold value when it is significantly higher in the considered cluster.
GENCOMP: Generic use of computer
GENINT: Generic use of Internet
ICTPED: Use of ICT for pedagogic purposes
ICTCOLL: Use of ICT for collaborative work purposes

The levels of student e-skills of the four clusters (profiles) are illustrated in Table 4 and can be interpreted as following:

Profile 1: Operational e-skills (ESKILLS_1). This group includes 25.96% of students (380 students) who are the later adopters of the ICT and do not use them intensively. They typically have text processing skills and have used some aspects of presentation and spreadsheets software. Generally, students from Profile 1 have not used specialized software or collaborative applications. They especially have the basic skills to operate the computer.

Profile 2: Formal e-skills (ESKILLS_2). This group includes 32.51% of students (476 students) who in addition to possessing the operational skills listed in Profile 1, declared to use Internet applications like search engine, network application and messaging software. Students from Profile 2 tend to have some information skills.

Profile 3: Information e-skills (ESKILLS_3). This group (356 students; 24.32%) is represented by students who are not proficient in ICT but have sophisticated learning mechanisms are willing to learn new ICT tools to reconstruct their learning practices. This group is also strong on operational and formal skills.

Profile 4: Strategic e-skills (ESKILLS_4). Students belonging to this group (252 students; 17.21%) are earlier adopters and use ICT intensively. They are characterized by high e-skills. In addition, the use of collaborative applications is widespread this cluster indicating that especially students who have expertise in and access to theses ICT tools are using ICT to support collaborative learning.

The four dummy variables ESKILLS_1, ESKILLS_2, ESKILLS_3 and ESKILLS_4 used in the econometric analysis below result from this procedure. They represent the four identified modes of ICT usages.

5.2. Independent variables

Students' characteristics: Gender, students' age, level of education, home university and having job while studying can be expected to influence student's e-skills levels.

ICT access: ICT access is measured by different items, which concern both ICT equipment such as the possession of a laptop or a computer at home, having domestic Internet connection and ICT help and support such as the availability of discipline-specific software, the

availability of help and support and ICT training provided by the university. The variables where coded as a "1" if the respondent answered with a "yes (=1)", otherwise a "no (=0)".

Students' involvement: Students' involvement reflects the students' effort in order to use ICT efficiently. This variable is measured by two items, which are first, student's ICT training, coded as a "1" if the respondent answered with a "yes (=1)", otherwise a "no (=0)". Second, students were also asked about the use of Internet for pedagogical purposes. They ranked the extent of their usage on a scale of five points (1-5) specifically, less than one hour per week (1), from 1 to 5 hours (2), from 6 to 9 hours (3), from 10 to 14 hours (4), and more than 15 hours (5).

Learning mechanisms: Two sets of variables were used to measure students' learning mechanisms: ICT learning by doing and ICT learning by using. In our survey we assume that a student accumulates ICT skills by doing if he tries out new applications, if he is an early tester of new computer applications or if he participates in applications development. Furthermore, three variables tap the ICT learning by using dimension. Two items assess mobile devices use: flexible versus fix scheduled work and use of mobile tools. The students were asked if working at any time during the day is more efficient than working at fixed time and whether they use mobile tools in order to prepare their homework. The responses are coded 1 if the respondent says "yes", 0 otherwise.

Collaborative and cooperative learning: In order to measure students' collaborative and cooperative learning, we use seven items. ICT use is seen as collaborative and cooperative learning tools when the student believes that Internet use enhances collaboration with other students, when he states that Internet use improves the work presentation and organization. This variable is also measured by the student's believe that Internet is useful to provide business creation ideas and innovative ideas, and that ICT are important for learning due to the fact that these tools give them the opportunity to contact the teacher or the tutor by e-mail. In addition, it measures the ability to communicate and to discuss a course issue online and the belief that Internet use enables to obtain a deeper understanding of the content developed in class. Respondents were asked to indicate the extent of their agreement with each item on a five-point scale, ranging from 1-strongly disagree to 5-strongly agree.

5. EMPIRICAL RESULTS

This section presents the empirical results of the determinants of students' e-skills in France. First, the goodness-of-fit tests for the model are presented. Second, the results from the estimated multinomial logit model and the marginal effects related to ESKILLS variable are presented and discussed. Finally, the results of the appropriateness of the model test are presented. The empirical results from the estimated multinomial logit model and the marginal effects are reported in tables 5 and 6. The log-likelihood value for the model is -1440.6086.

Table 5. Results from the multinomial logit model

Dependent variables Structural e-skills	Formal e-skills	Information e-skills	Strategic e-skills
Independent variables			
Student characteristics'			
Gender	0.03 (0.167)	-0.04 (0.193)	0.56 ** (0.249)
University			
University of Paris-Sud 11	Ref.	Ref.	Ref.
University of Nice-Sophia Antipolis	0.90*** (0.237)	-0.08 (0.289)	1.22*** (0.337)

University of Paris 10	0.28 (0.299)	-0.30 (0.350)	0.07 (0.439)
Level of education			
First year of undergraduate degree	Ref.	Ref.	Ref.
Second year of undergraduate degree	0.11 (0.217)	-0.07 (0.251)	0.11 (0.318)
Third and final year of undergraduate degree	0.10 (0.253)	0.32 (0.285)	0.64* (0.373)
Age			
17 to 19	Ref.	Ref.	Ref.
20 to 21	0.05 (0.214)	0.18 (0.247)	0.31 (0.309)
22 to 23	-0.22 (0.258)	-0.42 (0.297)	-0.48 (0.388)
24 and older	-1.30*** (0.474)	-1.49*** (0.531)	-2.10*** (0.780)
Having a job while studying	0.24 (0.178)	0.40** (0.201)	0.61*** (0.249)
ICT access			
Having a computer at home	-0.13 (0.242)	0.12 (0.293)	1.30*** (0.485)
Having a laptop	0.17 (0.188)	0.39* (0.233)	0.58* (0.320)
Internet connection at home	0.42 (0.386)	0.10 (0.497)	-1.27** (0.649)
Availability of discipline-specific software	0.04 (0.070)	0.26** (0.085)	0.27*** (0.113)
Availability of help and support	0.01 (0.069)	0.11 (0.079)	0.23** (0.105)
The university provides ICT training	0.52*** (0.169)	0.30 (0.199)	0.47* (0.267)
Students' implication			
Student ICT use training	0.18 (0.168)	0.50*** (0.190)	0.43* (0.240)
Hours spent per week surfing for pedagogical purposes			
Less than one hour	Ref.	Ref.	Ref.
1 to 5 hours	0.05 (0.191)	0.41* (0.247)	-0.30 (0.323)
6 to 9 hours	0.42 (0.293)	1.01*** (0.341)	0.06 (0.426)
10 to 14 hours	0.34 (0.489)	1.15** (0.520)	1.55*** (0.580)
15 hours and more	-0.33 (0.685)	0.62 (0.696)	1.76*** (0.716)
Learning mechanisms			
Learning by doing			
To test new applications	0.18 (0.111)	0.25** (0.130)	0.63*** (0.158)
Primary tester of new computer applications	0.43*** (0.107)	0.40*** (0.123)	0.38*** (0.146)
Applications development	0.25*** (0.085)	0.37*** (0.093)	0.44*** (0.106)
Learning by using			
Flexible versus fixed schedule	0.10 (0.067)	0.18** (0.077)	0.26*** (0.099)
Use of mobile tools	0.08 (0.063)	0.21*** (0.071)	0.41*** (0.091)
Collaborative and cooperative learning			
Internet use enhances collaboration with other students	0.25*** (0.077)	0.35*** (0.092)	0.52*** (0.122)
Internet use improves the work presentation and organization	-0.04 (0.081)	0.16* (0.096)	0.52*** (0.132)
Internet provides business creation ideas	0.14 (0.089)	0.12 (0.099)	0.55*** (0.122)
Internet provides innovative ideas	0.09 (0.090)	0.22** (0.102)	0.25** (0.135)
Having the opportunity to contact the teacher / tutor by e-mail	0.28*** (0.078)	0.39*** (0.096)	0.35*** (0.132)
Being able to communicate and discuss a course issues online	-0.09 (0.076)	0.22*** (0.088)	0.35*** (0.117)
Internet use enables to deepen the content developed in class	0.17** (0.077)	0.32*** (0.092)	0.44*** (0.124)
Pseudo R^2	27.76		
Log likelihood	-1440.6086		
LR(96)	1106.97***		

Note: The notation ***, **, and * denotes significance at the 1%, 5% and 10%.

The likelihood ratio $\left(\chi^2\right)$ value of 1106.97 is greater than the critical chi-square value $\left(\chi^2_{0.001}, 96\right)$ of 144.55 and $\left(\chi^2_{0.01}, 96\right)$ of 131.14 at the 0.1% and 1% levels of significance. This

test confirms that all the slope coefficients are significantly different from zero. The alternative hypothesis is thus accepted at these levels of significance.

Table 6. Marginal effects of the multinomial logit model

Dependent variables Structural e-skills	Formal e-skills		Information e-skills		Strategic e-skills	
	Exp(β)	Marginal Effects	Exp(β)	Marginal Effects	Exp(β)	Marginal Effects
Independent variables						
Student characteristics'						
Gender	1.03	0.005	0.96	-0.024	1.74**	0.035***
University						
Université Paris-Sud 11	Ref.	–	Ref.	–	Ref.	–
UniversitéNice-Sophia Antipolis	2.45***	0.179***	0.92	-0.156	3.38***	0.057***
Université Paris 10	1.32	0.107	0.74	-0.096	1.07	0.001
Level of education						
First year of undergraduate degree	Ref.	–	Ref.	–	Ref.	–
Second year of undergraduate degree	1.12	0.034	0.93	-0.032	1.12	0.005
Third and final year of undergraduate degree	1.11	0.040	1.38	0.039	1.90*	0.055
Age						
17 to 19 years	Ref.	–	Ref.	–	Ref.	–
20 to 21 years	1.06	-0.021	1.20	0.024	1.36	0.015
22 to 23 years	0.81	0.015	0.66	-0.048	0.62	-0.015
24 years and older	0.27***	-0.120	0.23***	-0.120*	0.12***	-0.047***
Having a job during studies	1.27	0.015	1.49**	0.038	1.84***	0.067**
ICT access						
Having a computer at home	0.88	-0.076	1.13	0.025	3.69***	0.056***
Having a laptop	1.19	0.026	1.48*	0.047	1.78*	0.077
Internet connection at home	1.52	0.150	1.11	0.024	0.28**	-0.171*
Availability of discipline-specific software	1.04	-0.033	1.30***	0.044***	1.31***	0.010*
Availability of help and support	1.00	-0.021	1.11	0.017	1.26**	0.012**
The university provides ICT training	1.68***	0.074**	1.35	0.015	1.61*	0.052
Students' implication						
Training at the use of ICT	1.19	0.039	1.65***	0.073***	1.53*	0.051
Hours spent per week surfing for pedagogical purposes						
Less than one hour	Ref.	–	Ref.	–	Ref.	–
1 to 5 hours	1.06	0.032	1.10*	0.084**	0.74	-0.030
6 to 9 hours	1.53	0.054	2.73***	0.163***	1.06	0.028
10 to 14 hours	1.41	0.146	3.16**	0.157**	4.71***	0.083*
15 hours and more	0.72	-0.229	1.86	0.087	5.82***	0.196**
Learning mechanisms						
Learning by doing						
Test of new applications	1.19	-0.009	1.28**	0.015	1.89***	0.030***
Primary tester of new computer applications	1.53***	0.041**	1.49***	0.037	1.47***	0.033
Applications development	1.29***	0.017	1.44***	0.034***	1.56***	0.013***
Learning by using						
Flexible versus fixed schedule	1.11	0.007	1.19**	0.018	1.30***	0.010**
Use of mobile tools	1.08	0.022	1.24***	0.026**	1.50***	0.019***

Collaborative and cooperative learning						
Internet use enhances collaboration with other students	1.29***	0.022	1.42***	0.029**	1.69***	0.018***
Internet use improves the work presentation and organization	0.96	-0.048	1.18*	0.029*	1.67***	0.031***
Internet provides business creation ideas	1.15	0.002	1.12	0.006	1.73***	0.028***
Internet provides innovative ideas	1.10	0.015	1.25**	0.029*	1.28***	0.038
Having the opportunity to contact the teacher / tutor by e-mail	1.32***	0.025	1.47***	0.037***	1.42***	0.066
Being able to communicate and discuss a course issues online	0.91	-0.064	1.25***	0.052***	1.42***	0.021***
Internet use enables to deepen the content developed in class	1.19**	0.014	1.37***	0.034**	1.56***	0.056***

Note: The notation ***, **, and * denotes significance at the 1%, 5% and 10%.

The parameter estimates indicate the impact of a unit change in the explanatory variables on log-odds ratios. The results confirm the expected signs of the coefficients of the students' characteristics and the ICT access. The results indicate that student's characteristics, ICT access, student's implication, learning mechanisms, and collaborative and cooperative learning are crucial when explaining the probability that a student will be classified in one of the different categories of e-skills.

Table 6 shows that male students, ICT accessibility, ICT affordability, intensive learning by using, high collaborative and cooperative learning increase the probability of having information or strategic e-skills compared to the probability of having structural e-skills.

The associated negative values (effects) imply, in the case of the ESKILLS_2 category, that a unit increase of the variable of interest reduces the probability of having formal e-skills compared to the probability of having structural reference e-skills. In the case of the ESKILLS_3 category, a unit increase in the variable reduces the probability of having information e-skills compared to the probability of having structural e-skills.

The marginal effects (ME) and the odds-ratios (reported under the $Exp(\beta)$) show the magnitude of the already identified increases. The estimation reveals that the student's gender has a statistically significant effect on the probability of having strategic e-skills. The estimated odds-ratio for male is 1.74 for ESKILLS_4 category suggesting that the predicted odds for male, in order to be classified in the strategic e-skills category, increases by a multiplicative factor of 1.74 or, simply, that the change increases the odds of having strategic e-skills instead of having only structural e-skills by 74% in the considered category.

Regarding students' age, older students are less likely to have all types of e-skills compared to relatively young ones (17-19 age group). This means that an increase by one unit of student's age will significantly enhance the probability of having operational e-skills by 73%, 77% and 88% for the 24 and more age group in ESKILLS_2, ESKILLS_3 and ESKILLS_4 categories, respectively.

Concerning having job while studying, a unit increase would multiply the odds of having ESKILLS_3 compared to having ESKILLS_1 by 1.49 and the odds of having ESKILLS_4 rather than ESKILLS_1 by 1.84, implying an increase in the odds by 49% and 84% respectively.

With regard to ICT access, the availability of equipment tends to improve the probability of having information and strategic e-skills and mainly strategic ones. For instance, concerning

having a computer at home, an increase by one unit will significantly enhance the odds of having strategic e-skills compared to having operational e-skills by 3.69 implying almost three time odds' increase. Furthermore, help and support have a positive and significant impact on having strategic e-skills compared to operational e-skills. An increase of one unit improves the odds by 1.26, which means an increase of 26% of strategic e-skills. Nevertheless, regarding "providing ICT training by the university"; an increase by one unit enhances significantly the odds of having formal e-skills compared to the reference category by 1.68 reflecting an increase of 68% of the odds of having formal e-skills.

Student's implication

Regarding students' involvement, with respect to "ICT use training by students", an increase by one unit enhances significantly the odds of having information e-skills by 1.65 compared to operational e-skills implying an increase of 65% of the odds. Concerning time spent surfing on the Internet for learning purposes, the more the student spent time surfing the more the probability of having strategic e-skills compared to structural e-skills increases. For instance the odd-ration of 5.82 means that one additional unit of student who spent more than 15 hours surfing on the Internet increase by almost six times the probability of having strategic e-skills compared to structural e-skills. Our estimates show clearly how a structural change in the Higher Education may improve the acquisition of e-skills. Students' involvement by giving them the incentives to spend more time on Internet for pedagogical uses and for following courses related to ICT increase their probability to acquire e-skills. Moreover involvement impacts the nature of these e-skills. It allows students to acquire high level of e-skills (strategic and informational skills).

Diversity of learning mechanisms

Concerning learning mechanisms, ICT learning by doing has a significant and positive effect on all types of e-skills, e.g., application development increase by one unit raises significantly the odds of having respectively formal e-skills, information e-skills and strategic e-skills by 29%, 44% and 56% referring to operational e-skills.

Learning by using enhances significantly information and strategic e-skills compared to operational e-skills. For instance, one unit's increase of mobile use for studies multiplies the odds of having information and strategic e-skills by 1.24 and 1.50 respectively rather than operational e-skills, which means an increase of the odds by 24% and 50% respectively.

Again, these findings are suggestive for the need for structural changes in universities to diversify the forms of learning mechanisms. This diversity of learning mechanisms improves the acquisition of all the forms of e-skills. At the same time we have seen their large impact on strategic skills.

Collaboration and cooperation

With regards to collaborative and cooperative learning, items in general reflect a positive and significant impact on the probability of having information and strategic e-skills compared to structural ones. In fact, with respect to students' view that Internet use enhances collaboration with other students, one unit increase multiply the odds of having information e-skills and strategic e-skills by 1.42 and 1.69 respectively. In other words, the fact that Internet use enhances collaboration with others increases significantly the probability of having ESKILLS_3 and ESKILLS_4 by respectively 42% and 69%. Furthermore, an increase of the belief that ICT gives students the opportunity to contact the teacher by e-mail by one unit

multiply the odds of having formal e-skills, information e-skills and strategic e-skills by respectively 1.32, 1.47 and 1.42, which means an increase in the odds of 32%, 47% and 42% respectively.

Again this suggests a powerful impact of organizational change in the process of e-skills acquisition. Encouraging collaborative learning and improving the cooperation between student through the use of ICT inside and outside the classroom allow them to acquire the valuable e-skills (in particular, strategic skills).

We summarize our three key set of results.

Firstly, students' involvement increases the accumulation of their e-skills. The results of this study indicate that students' involvement enhances students' e-skills. ICT training enhances students' information e-skills. This could be explained by combining basic e-skills with learning through training based on ICT use leading to more sophisticated e-skills. Spending more hours surfing on the Internet for learning purpose also improves students' e-skills. Students who spend more time surfing on the Internet have a more sophisticated e-skills.

Secondly, the diversity of learning processes enhances the accumulation of students' e-skills. The outcomes regarding the relationships among learning processes and students' e-skills show the importance of ICT learning by doing and ICT learning by using to enhance e-skills. While ICT learning by doing enhances all types of e-skills, ICT learning by using enhances information e-skills and mainly strategic e-skills. This result shows the importance of using ICT tools to improve the more sophisticated e-skills. Thus, strategies based on facilitating ICT learning by using are needed. These strategies could be reflected by letting students using ICT tools for learning purpose and letting them working in team in prder to use frequently distant tools (e.g. e-mail, videoconference...).

Thirdly, collaborative and cooperative learning facilitates the accumulation of students' e-skills. As technological change and organizational change are considered to be complementary, an effective ICT use at universities, as well as at firms, requires collaborative and cooperative competencies as both academic and professional environments undergo changes. When students understand that ICT tools facilitate the communication between them and with teachers (which tends to improve their knowledge and then their performance) they tend to use ICT more often. This in turn enhances their more sophisicated e-skills.

6. Concluding remarks

The complementarity between organizational change and the use of ICT allows students to acquire more efficiently e-skills. Internal organizational changes in universities are similar to those observed within modern firms (team work, project work, total quality, collaborative work, distant work, modular work, autonomy…). Students improve their employability in the job market by acquiring organizational and e-skills at university.

The results of the multinomial logit model for French data from 2010 confirm the hypothesis of the complementarities between organizational change and ICT. In fact, our study contributes to a growing body of literature discussing students' e-skills accumulation. ICT integration in higher education has been gaining steady interest over the past decade. However, challenges remain in implementing the right organizational changes in order to support the use of ICT and to enhance students' e-skills acquisition. Higher education

institutions also may be blatantly or inadvertently blocking ICT development due to incoherent plans for inclusion and misunderstandings of the needed organizational changes. Our article has analyzed how changes in the organization of learning can impact different types of e-skills acquisition by students and the nature of these skills. Further research is needed in order to extend the findings to other socio-cultural contexts.

REFERENCES

[Angrist and Lavy2002]Angrist, J. D. and Lavy, V. (2002). New evidence on classroom computers and pupil learning. *The Economic Journal*, 112(482):735–786.

[Arvanitis and Loukis2009]Arvanitis, S. and Loukis, E. N. (2009). Information and communication technologies, human capital, workplace organization and labour productivity: A comparative study based on firm-level data for greece and switzerland. *Information Economics and Policy*, 21(1):43–61.

[Askenazy2000]Askenazy, P. (2000). *Innovations and employment: evidence from American manufacturing*, chapter Chapter 6, pages 96–120. Routledge, London, 1 edition.

[Askenazy et al.2001]Askenazy, P., Caroli, E., and Marcus, V. (2001). New organizational practices and working conditions: evidence from france in the 1990s. CEPREMAP Working Papers (Couverture Orange) 0106, CEPREMAP.

[Askenazy and Gianella2000]Askenazy, P. and Gianella, C. (2000). Le paradoxe de productivité : les changements organisationnels, facteur complémentaire à l'informatisation. *Ã‰conomie et Statistique*, 339(1):219–241.

[Banerjee et al.2007]Banerjee, A. V., Cole, S., Duflo, E., and Linden, L. (2007). Remedying education: Evidence from two randomized experiments in india. *Quarterly Journal of Economics*, 122(3):1235–1264.

[Barak et al.2006]Barak, M., Lipson, A., and Lerman, S. (2006). Wireless laptops as means for promoting active learning in large lecture halls. *Journal of Research on Technology in Education*, 38(3):245–263.

[Ben Youssef and Dahmani2008]Ben Youssef, A. and Dahmani, M. (2008). Uses of information and communication technologies in europe's higher education institutions: From digital divides to digital trajectories. *Revista de Universidad y Sociedad del Conocimiento, RUSC*, 5(1):45–56.

[Ben Youssef and Hadhri2009]Ben Youssef, A. and Hadhri, W. (2009). Les dynamiques d'usage des technologies de l'information et de la communication par les enseignants universitaires : le cas de la france. *Réseaux*, 27(155/2009):25–54.

[Black and Lynch2001a]Black, S. E. and Lynch, L. M. (2001a). How to compete: The impact of workplace practices and information technology on productivity. *The Review of Economics and Statistics*, 83(3):434–445.

[Black and Lynch2001b]Black, S. E. and Lynch, L. M. (2001b). What's driving the new economy? the benefits of workplace innovation. Staff Reports 118, Federal Reserve Bank of New York.

[Blass2005]Blass, E. (2005). The rise and rise of the corporate university. *Journal of European Industrial Training*, 29(1):58–74.

[Bocquet and Brossard2007]Bocquet, R. and Brossard, O. (2007). The variety of ICT adopters in the intra-firm diffusion process: Theoretical arguments and empirical evidence. *Structural Change and Economic Dynamics*, 18(4):409–437.

[Bresnahan et al.2002]Bresnahan, T. F., Brynjolfsson, E., and Hitt, L. M. (2002). Information technology, workplace organization, and the demand for skilled labor: Firm-level evidence. *The Quarterly Journal of Economics*, 117(1):339–376.

[Caroli2001] Caroli, E. (2001). Organizational change, new technologies and the skill bias: What do we know? In Petit, P. and Soete, L., editors, *Technology and the Future of European Employment*, pages 259–292. Edward Elgar.

[Caroli and Van Reenen2001]Caroli, E. and Van Reenen, J. (2001). Skill-biased organizational change? evidence from a panel of british and french establishments. *The Quarterly Journal of Economics*, 116(4):1449–1492.

[Fernandez2007]Fernandez, J. A. (2007). The future of corporate universities in europe. *Global Focus*, 2(2):40–43.

[Fonstad and Lanvin2009]Fonstad, N. and Lanvin, B. (2009). Synthesis report for the european e-competences curricula development guidelines project. Background report prepared by insead elab for the european business summit 2009, INSEAD eLab.

[Franses and Paap2001]Franses, P. H. and Paap, R. (2001). *Quantitative Models In Marketing Research*. Cambridge University Press, Cambridge, 1 edition.

[Goldfarb2006]Goldfarb, A. (2006). The Teaching role of Universities in the diffusion of Internet. *International Journal of Industrial Organization*, 24(2):203–225.

[Greenan1996]Greenan, N. (1996). ProgrÃ¨s technique et changement organisationnels: leur impact sur l'emploi et les qualifications. *Economie et Statistique*, 298(1):35–44.

[Greenan and Mairesse2004]Greenan, N. and Mairesse, J. (2004). A Firm Level Investigation of the Complementarity between Information and Communication Technologies and New Organizational Practices. In *79th Annual conference of the Western Economic Association International. June 29-July 3, 2004*, Vancouver, Canada.

[Greenan and Walkowiak2006]Greenan, N. and Walkowiak, E. (2006). Information technology, work organisation and social interactions. *Economie et Statistique*, 387:35–63.

[Hair et al.2006]Hair, J. F., Black, W. C., Babin, B. J., and Anderson, R. E. (2006). *Multivariate Data Analysis*. Pearson Prentice Hall, Upper Saddle River, New Jersey, 7ème edition.

[Hakkarainen et al.2000]Hakkarainen, K., Ilomaki, L., Lipponen, L., Muukkonen, H., and Rahikainen, M. (2000). Students skills and practices of using ict : Results of a national assessment in finland. *Computers and Education*, 2:103–117.

[Hoskins and van Hooff2005]Hoskins, S. L. and van Hooff, J. C. (2005). Motivation and ability: which students use online learning and what influence does it have on their achievement? *British Journal of Educational Technology*, 36(2):177–192.

[Ichniowski et al.1997]Ichniowski, C., Shaw, K., and Prennushi, G. (1997). The effects of human resource management practices on productivity: A study of steel finishing lines. *American Economic Review*, 87(3):291–313.

[Jonassen et al.2005]Jonassen, D., Lee, C. B., Yang, C.-C., and Laffey, J. (2005). The collaboration principle in multimedia learning. In *The Cambridge Handbook of Multimedia Learning*, pages 247–270. Richard Mayer.

[Keengwe et al.2009]Keengwe, J., Onchwari, G., and Onchwari, J. (2009). Technology and student learning : Toward a learner- centered teaching model. *AACE Journal*, 17(1):11–22.

[Kolding and Kroa2007]Kolding, M. and Kroa, V. (2007). E-skills: The key to employment and inclusion in europe. Technical report, IDC White Paper, London.

[Lundberg et al.2008]Lundberg, J., Dahmani, M., and Castillo-Merino, D. (2008). Do online students perform better than face-to-face students? reflexions and a short review of some empirical findings. *Revista de Universidad y Sociedad el Conociamento, RUSC*, 5(1):35–44.

[Machin et al.2007]Machin, S., McNally, S., and Silva, O. (2007). New technology in schools: Is there a payoff? *Economic Journal*, 117(522):1145–1167.

[Maddala1993]Maddala, G. S. (1993). *Limited-Dependent and Qualitative Variables in Econometrics*. Cambridge University Press, Cambridge.

[Malhotra2009]Malhotra, N. K. (2009). *Marketing Research: An Applied Orientation*. Prentice Hall, Upper Saddle River, New Jersey.

[Nicol and MacLeod2005]Nicol, D. J. and MacLeod, I. A. (2005). Using a shared workspace and wireless laptops to improve collaborative project learning in an engineering design class. *Computers and Education*, 44(4):459–475.

[Nunnally and Bernstein1994]Nunnally, J. and Bernstein, I. (1994). *Psychometric theory*. McGraw-Hill, New York, 3ème edition.

[OECD2006]OECD (2006). *Education Policy Analysis: Focus on Higher Education*. OECD, Paris.

[Pavitt1985]Pavitt, K. (1985). Patent statistics as indicators of innovative activities: Possibilities and problems. *Scientometrics*, 7(1,2):77–99.

[Rivkin et al.2005]Rivkin, S. G., Hanushek, E. A., and Kain, J. F. (2005). Teachers, schools, and academic achievement. *Econometrica*, 73(2):417–458.

[Saulnier et al.2008]Saulnier, B. M., Landry, J. P., Longenecker, H. E., and Wagner, T. A. (2008). From teaching to learning : Learner-centered teaching and assessment in information systems education. *Journal of Information Systems*, 19(2):169–175.

[SEUSISS Project Final Report2003]SEUSISS Project Final Report (2003). Survey of european universities skills in ICT of students and staff. Technical report.

[Sharma1995]Sharma, S. (1995). *Applied Multivariate Techniques*. John Wiley and Sons, Inc, New York.

[Steyaert2002]Steyaert, J. (2002). Inequality and the digital divide: myths and realities. In McNutt, S. H. . J., editor, *Advocacy, activism and the internet*, pages 199–211. Lyceum Press., Chicago.

[Su2008]Su, K.-D. (2008). An integrated science course designed with information communication technologies to enhance university students' learning performance. *Computers and Education*, 51(3):1365–1374.

[Thijs et al.2001]Thijs, A., Almekinders, R., Blijleven, P., Pelgrum, W., and Voogt, J. (2001). Learning through the web: a literature study on the potential uses of the web for student learning. Technical report, University of Twente, Faculty of Educational Science and Technology, Department of Curriculum, Enschede.

[Triplett1999]Triplett, J. E. (1999). The solow productivity paradox: what do computers do to productivity? *Canadian Journal of Economics*, 32(2):309–334.

[Tuparovaa and Tuparova2010]Tuparovaa, D. and Tuparova, G. (2010). Automated real-live performance-based assessment of ict skills. *Procedia - Social and Behavioral Sciences*, 2(2):4747–4751.

[van Deursen and van Dijk2010]van Deursen, A. J. A. M. and van Dijk, J. A. (2010). Measuring internet skills. *International Journal of Human-Computer Interaction*, 26(10):891–916.

[van Dijk2005]van Dijk, J. A. (2005). *The Deepening Divide Inequality in the Information Society*. Sage Publications, Thousand Oaks, California.

[van Dijk2006]van Dijk, J. A. (2006). Digital divide research, achievements and shortcomings. *Poetics*, 34(4-5):221–235.

[Zammit2004]Zammit, L. (2004). Literacy in ict skills. Technical report, The Lisbon Objectives and the Maltese Education Provision.