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MULTIDIMENSIONAL ANALYSIS OF THE INTEGRATION FACTORS OF ICT IN EDUCATION: A CASE STUDY THROUGH THE MOROCCAN GENIE PROGRAM

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ABSTRACT: *With the aim of ensuring scientific dissemination that we describe the English version of our article published in French in ESJ (Samiha, 2016). This article focuses on the integration of ICT in high-school level within the framework of teaching of Life and Earth Sciences (SVT in French). The experimentation was conducted with a sample of 112 Moroccan teachers from the region of Fez-Boulemane, who responded to a questionnaire of 16 modalities related to the availability and the use of ICT tools, the educational management of ICT in class, and the trainings and competencies of the teachers in ICT and computing. In order to make an original contribution to the study of the integration of ICT, we adopted a multidimensional analysis in the treatment of the answers of the teachers. Thus, thanks to a Factorial Analysis of Multiple Correspondence (FAMC), we could take account of the links which exist between the various modalities of our questionnaire to get to identify the most discriminating factors in the integration of ICT, according to their order of importance. The results of this analysis led to three factorial axes cumulating an absolute inertia of 70%, respectively representing «the pedagogical contribution and the fundamental conditions of a successful integration of ICT», «the advanced competencies in ICT and computing» and «the difficulties of using ICT in class». These axes, in this hierarchy, ultimately represent the most discriminating factors for a successful integration of ICT.*

KEYWORDS: Integration of ICT, Secondary education, Life and Earth Sciences, Multi-dimensional Analysis, Discriminating factors.

INTRODUCTION

The use of Information and Communication Technologies (ICT) is now a social practice that is developing very quickly, incorporating all sectors, including the educational sector. The remarkable increase of information and the extraordinary development of knowledge have led the integration of ICT in teaching and learning to currently become an unavoidable issue in the educational world of any society (Matoussi, 2006). Various studies and researches are thus conducted about the integration of ICT in the sphere of education; and the results of these works are not always consistent (AFD, 2010). A major reason for these differences, and that we could talk about strictly enough, seems to be the intrinsic characteristics of the noosphere of the education system itself, as well as the specifics of the educational system being studied (Eurydice, 2011). Thus, the educational policies and educational systems of

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each country, among others, will have a significant impact on the integration of ICT and its success with learners, which is why we sought to bring a new contribution to the issue of integration of ICT in the Moroccan educational system.

The High Orientations in the speech of the King of Morocco (23 April 2001) on the "Morocco in the global society of information and knowledge", have led the Ministry of Education to conduct for some years now a policy in favor of the use of Information and Communication Technologies. The latter policy is, moreover, the one advocated by The National Charter of Education and Training 1999 (COSEF Morocco, 1999). In this way, several major national programs have been launched in recent years for the integration of ICT in the Moroccan educational system:

- The 2006-2013 GENIE program,

- The 2009-2012 emergency plan (Area 1, Project 10)

- The Morocco Numéric Strategy 2020,

- The INJAZ program.

In addition, a national portal "Taalimtice or Portailtice" was set up in 2011 aiming to enable all players in the Moroccan educational system to get trained and learn about ICT, exchange information, and actively participate in the development and diffusion of ICT.

We therefore sought to contribute to the study of the progress of the integration of ICT in Morocco, by exploring the issue with the teachers of the Life and Earth Sciences (SVT in French) subject at secondary school level. We wanted to adopt a situation analysis approach which is different from those adopted so far by the various studies and researches carried out in Morocco (El Ouidadi, O., 2012; Lakdim, A et al, 2012;. Alj, O . 2014; Ouazzani Thami, A., 2014; Droui, M., 2015) in order to better understand the issues related to the effectiveness of policies carried out in terms of the integration of ICT, the conditions of its success, as well as the challenges faced by teachers when integrating ICT in class.

Theoretical framework and research problem

Research over the past decade on the integration of ICT in the Moroccan secondary education is a quite rich theoretical framework for introducing our own research problem.

These works investigated the effects of the integration of ICT tools in the secondary-tertiary transition, as is the case in the work of Ouazzani A. (2014) who worked on the conceptual difficulties in geometrical optics and showed a few effects of remediation with students through the use of a Java Geometrical Optics Workshop (AJOG). The research by Droui M. (2015) are also related to the same type of problem; he shows that an active learning based on simulation and ExAO promotes a better understanding of Newton's laws.

As for us, we are also interested in the integration of ICT, but according to an approach that is considered complementary to those of the two previous research works. Our problem is close to those of O. El Ouidadi (2012), Maouni (2014), El Madhi (2014) and O. Alj (2014), which respectively made a status report on the integration of ICT in the Moroccan secondary education, through the questioning of teachers: the first three were interested in Life and Earth Sciences (SVT), as is the case with us; and the last one was interested in physical

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sciences and algorithm. These works, all based on descriptive statistical analysis, agree on several constraints relating to the integration of ICT:

• Lack of techno-pedagogical skills

• Lack of digital resources

• Disparity of computer equipment between educational institutions and difficulty of equipment maintenance

• Disparity of teachers' skills and their training in ICT

Our approach to the issue of the integration of ICT differs from previous ones by its analysis methodology of the surveyed teachers' answers. Indeed, in our research issue, we will seek, through multifactorial statistical methods, to answer the following questions:

• What are the links that may exist between the constraints of ICT integration?

• What interpretations can be given to tendencies that represent these links?

• What are, in terms of degree of importance, the quantifications of these tendencies; and what are those having priority?

• And finally, we will make a distinction between the most discriminating constraints vis-à-vis the issue of integration of ICT in education, and those whose effect on this integration is rather unimportant.

Experimentation and research methodology

Our research question deals with the integration of ICT, according to an investigation that targets secondary teachers of Life and Earth Sciences (SVT in French). We therefore sought to address this issue comprehensively in the region of Fès-Boulemane, the region that hosts our University of Sidi Mohammed Ben Abdellah in Fez.

The Regional Academy of Education and Training (AREF in French) of Fès-Boulemane (institutional and regional representative of the Ministry of Education and Training) is at national level one of the largest academies across the Moroccan territory, with a total of 253 SVT secondary school teachers. So after a formal approval of the AREF of Fès-Boulemane, we worked with a sample of 112 SVT teachers, which consisted of 97 teachers within urban areas (Fes, Sefrou and Missour) and 15 teachers within rural areas (Ribat El Kheil, El Menzel, Outat El Haj, Immouzer Marmoucha and Guigou). We can thus greatly introduce for our research the hypothesis that our sample is complete and represents the whole of SVT teachers working for the AREF of Fès-Boulemane.

The experimental approach adopted by our research, was based on the questioning of our sample by means of a questionnaire, a process which seven months during the 2013/2014 academic year. Moreover, the relatively large sample size (112 teachers) allows conducting in good conditions the study of discriminating factors of the integration of ICT through a multidimensional analysis.

The questionnaire (see Annex A), consists of 17 items, was established around the following points:

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• Availability and use of ICT tools.

• Pedagogical management of ICT in class.

• Training and skills in ICT and Computing.

These three points are the fundamental elements to address the issue of integration of ICT, they are also found in part in previous research work, particularly in El Ouidadi (2012) and El Madhi (2014) for SVT, and Alj (2014) and Droui (2015) in physics. These previous works, all based on descriptive statistical analyzes, have identified several factors that impede the integration of ICT, for example:

• insufficient training of teachers,

• the lack of infrastructure and equipment in institutions,

• lack of regular maintenance of equipment.

• overcrowded classes,

• the lack of planning and technical support to integrate ICT,

The identification of these factors is certainly fundamental and important to carry out the issue of integration of ICT; however, the use of simple descriptive statistics alone cannot inform us about more fundamental questions:

• What links exist between these factors?

• What are the factors that contribute most to these links?

• What is the order of importance of the discriminating factors explaining these links?

To answer all these questions, it will of course take conducting a descriptive analysis, but with a multidimensional character. The Factorial Analysis of Multiple Correspondence (FAMC) seems to be appropriate for this type of analysis, especially since we have 16 items in several modalities, that is to say, 16 qualitative variables that we will treat with a relatively large sample of 112 teachers. Such an analysis, based on the mathematical principle of dimensional reduction, will enable us to determine, in terms of links, the modalities of variables that are most discriminating, and to deduce the nature of its compound factors based on the links of those modalities, as well as their order of importance.

Interpretation of the Factorial Analysis of Multiple Correspondence (FAMC) results

The treatment of responses given by 112 teachers was carried out by an FAMC using the version 21 of the SPSS (Statistical Pakage for the Social Sciences) data processing software. Starting from the fundamental principle of dimension reduction of the FAMC, we sought first to identify the variable modalities whose contributions related to the construction of the factorial axes are negligible. A first FAMC conducted with all 16 items enabled us to identify these variables, which has eliminated questions related to the following items:

• Availability of a computer

• Internet browsing time

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• Availability of a computer room in the institution

• Use of the simulation in progress

• Use of ICT for lesson planning

A second FAMC was performed, in which we have only activated the remaining 11 items out of the 16 initial items. Compared to the results of the FAMC with the 16 initial items, the second FAMC resulted in almost the same distribution of discrimination measures for the remaining 11 items: This confirms again the justification of eliminating the questions related to the five items above, and confirms that their removal does not affect in any way the essence of the information contained in all teachers' answers to the questionnaire.

The second FAMC, limited to 11 items, led to three values $\lambda1 = 4{,}338$, $\lambda2 = 2{,}176$ et $\lambda3 = 1{,}085$, all three representing one explained inertia worth 69.081%. Thus, the inertia explained by the first three factorial axes is around 70%, so we will limit ourselves in the interpretation of the FAMC to the first three factorial axes. Moreover, since each of these three values are of order of multiplicity 1 ($\lambda1 > \lambda2 > \lambda3$), each of the three factorial axes will be interpreted separately.

Interpretation of the first factorial axis:

The FAMC has led to an absolute inertia of 39.43% for the first factorial axis, slightly more than a third of the total inertia of the cloud represented by all active variables, which is an important part of all of the information processed. The variables that contributed most to the formation of the first factorial axis are as follows:

Table 1: Variables with large contributions in the construction of the first factorial axis

Title of variables (Modalities)	**Contribution related to the Axis 1**
Interactivity of students (S_Interact_Yes and S_Interact_No)	0,933
Use of ICT tools (O_ICT_F and O_ICT_NF)	0,907
Participation of students in the use of ICT (S_ICT_Yes and S_ICT_No)	0,898
Skill in Office (OF_S (Sufficient) and OF_INS (Insufficient))	0,867
Type of training (T_Institu (Institutional) and T_Auto (Self-training)	0,448
Training in ICT (T_ICT_Yes and T_ICT_No)	0,260

The first factorial design (Axis 1, Axis 2) (See Figure 1) shows that there is a perfect opposition to the first factorial axis between the modalities representing the presence (Yes) and absence (No) of these variables. Thus, the first factorial axis separates, on the one hand (the side of the negative components), the modalities S_Interact_Yes, O_ICT_T, S_ICT_Yes, OF_S (Sufficient), T_Institu (Institutional), T_ICT_Yes, and, on the other hand, the opposite of these modalities (the side of the positive components), namely, S_Interact_No, O_ICT_NF, S_ICT_No, OF_INS (Unsatisfactory), T_Auto (Self-Study) T_ICT_No.

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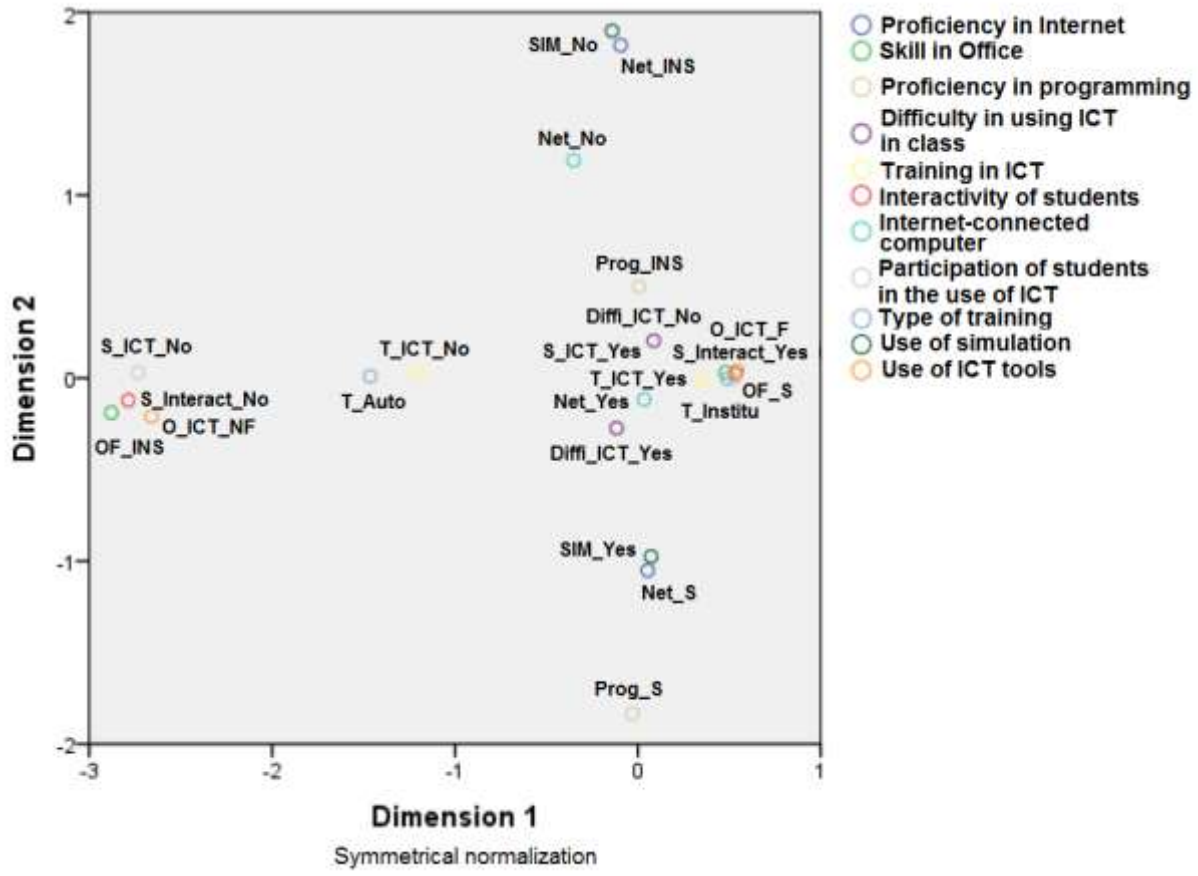

Figure 1: Diagram of variable modalities: First factorial design (Axis 1, Axis 2)

This perfect opposition between these two opposing groups of modalities allows initially concluding that the questionnaire we used to explore the issue of integration of ICT in education is well built and coherent as a whole with regard to the aforementioned research issue.

The variables corresponding to the largest contributions to the construction of the first factorial axis are, in order of importance (see Table 1):

• Interactivity of students

• Use of ICT tools

• Student participation in the use of ICT

• Proficiency in Office

The interpretation of the first factorial axis becomes thus immediate, it is about the axis representing "the educational benefit and the basic conditions for a successful integration of ICT." Indeed, if we take into account the two other variables ("Type of Training" and "Training in ICT"), which also contributed to the construction of the first factorial axis, we see that this axis reflects the successful integration ICT in education by:

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• First, its educational benefit in terms of "Interactivity of students", through their familiarity with the digital environment that is expressed in the first factorial axis by "Participation of students in the use of ICT".

• Next, the basic conditions for this success, namely the use of ICT tools in education (O_ICT_T modality of the variable "Use of ICT Tools"), which must be supported by the teacher. The latter should preferably have an institutional training (T_ICT_Yes and T_Institu modalities of the respective variables "Training in ICT'' and "Type of training"), particularly in relation to the Office pack (OF_S modality (Sufficient) of the variable "Proficiency in Office ").

Thus we can already conclude, from the interpretation of the first factorial axis, that a successful integration of ICT in the teaching of SVT, and most likely any other scientific subject, is primarily dependent on a purely didactical aspect, namely "the interactivity of students" in a digital environment built by the students themselves. The success of such integration requires the teacher to meet some minimum conditions: a mastery of Office softwares (Word, Excel, PowerPoint, Paint, Photoshop...), following an institutional training (as opposed to self-training); which is indeed an important component of the GENIE program.

4.2. Interpretation of the second factorial axis:

The FAMC has led to an absolute inertia of 19.78% for the second factorial axis. The following table summarizes the variables with the highest contributions to the second factorial axis:

Table 2: Variables with large contributions to the construction of the second factorial axis

Variable title (Modalities)	Contribution related to the Axis 2
Proficiency in Internet (Net_S (Sufficient) and Net_INS (Insufficient))	0,850
Use of simulation (SIM_Yes _F and SIM_No)	0,823
Proficiency in programming (Prog_S (Sufficient) and Prog_INS (Insufficient))	0,408

As can be seen in the first factorial design (see Figure 1), there is again a perfect contrast between, on the one hand, the modalities which represent a sufficient presence of skills related to the three variables "proficiency in Internet", "use of simulation" and "proficiency in programming", with positive components on the second factorial axis, and, on the other hand, the correspondent modalities that show the lack of proficiency related to the three mentioned variables, with negative components vis-à-vis the second factorial axis. This perfect opposition one more proves the right coherence of the questionnaire used.

The second axis is interpreted naturally as the axis of "Advanced skills in ICT and computing". Indeed, the largest contribution to this second axis refers to the variable "proficiency in Internet", which of course reflects a fundamental skill in the successful integration of ICT in education. As for the two other variables that contributed to the construction of this axis, namely "use of simulation" and "proficiency in programming". They refer to advanced computing skills. Thus, the second factorial axis highlights other additional conditions by the teacher, namely skills in both ICT and computing: Internet skills, computer programming and simulation, seem to rank second in comparison to the basic requirements suggested by the first factorial axis, but

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they represent advanced skills for a better integration of ICT in education, particularly when it comes to Life and Earth Sciences (SVT), or any other experimental school subject.

Validation of the interpretation of the first factorial design (Axis 1, Axis 2)

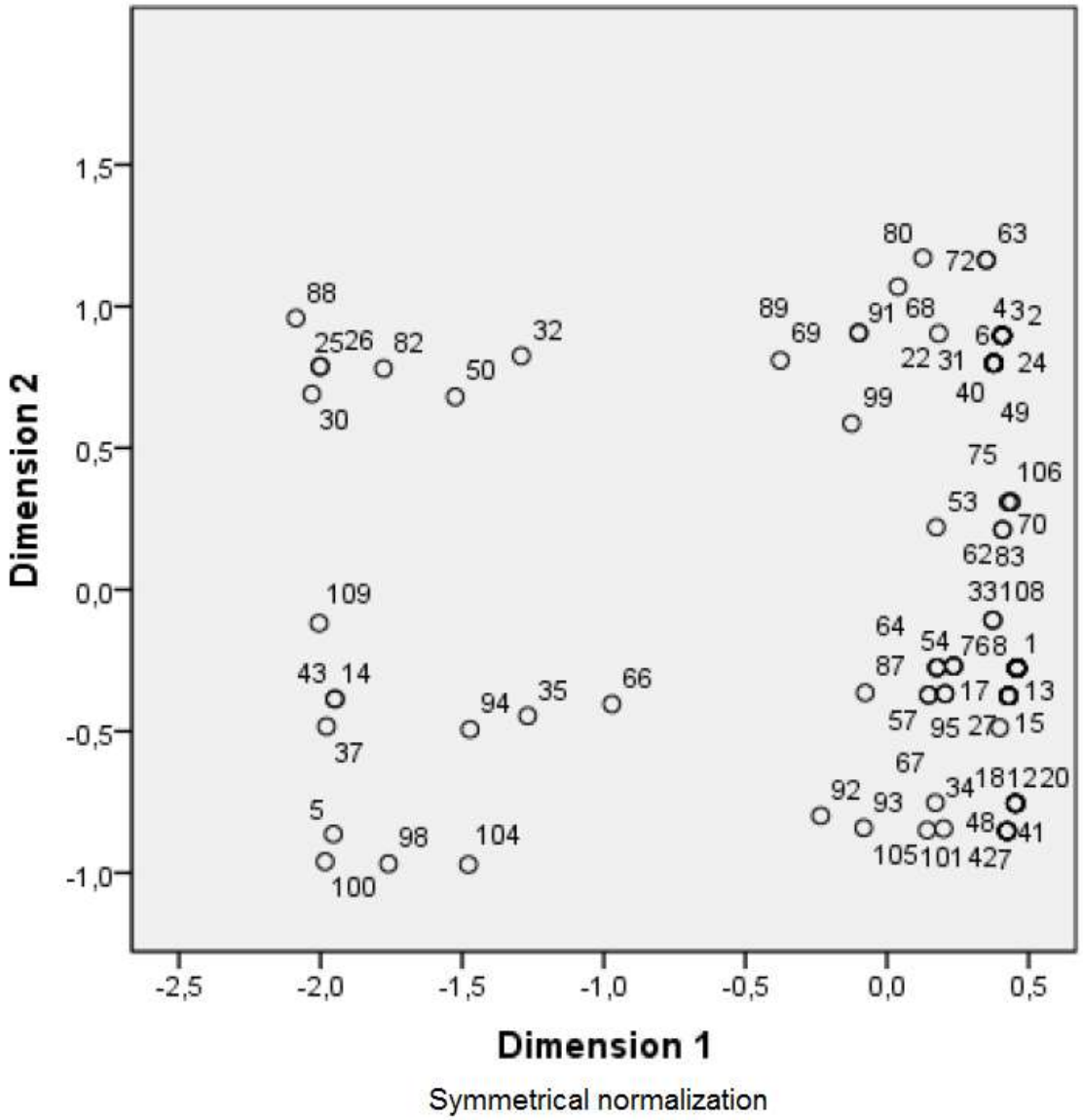

Figure 2: Projection of individuals for the first factorial plan (Axis 1, Axis 2)

The projection of the individuals questioned on the first factorial plan confirms the interpretations given to the first two factorial axes 1 and 2 (see Figure 2). Indeed, by seeking individuals who have the largest contributions to the first factorial plan (Axis 1, Axis 2), with the best representation quality, we obtained the following results:

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Table 3: Individuals with large contributions to the construction of the first factorial plan

Individuals	Contribution / Axis 1	Quality /Axis 1	Contribution / Axis 2	Quality / Axis 2	Component / Axis 1	Component / Axis 2
30	**0,059**	**0,858**	(0,010)	(0,070)	**2,563**	**-1,035**
63	(0,02)	(0,052)	**0,027**	**0,407**	**-0,442**	**-1,744**
72	(0,02)	(0,052)	**0,027**	**0,407**	**-0,442**	**-1,744**

The individual "30" is the one that has the largest contribution to the first factorial plan, with a contribution to the first axis of 0.059 (and a quality representation / Axis 1 of 0.858). The two components of this individual in the first factorial design are negative and large in absolute value: The analysis of this individual's response profile shows that this individual has a computer connected to the Internet; however, this individual answered "No" to all the remaining items in the questionnaire: this is the same profile of the extreme teacher who completely rejects the integration of ICT in education, as well as any related training in ICT in education, whether it is institutional or personal. This profile completely confirms the interpretation attributed to the first factor axis.

The two individuals "63" and "72" have exactly the same contribution to the first factorial plan, with the largest contribution on the second factorial axis, with a value of 0.027, and the best representation of this factorial axis (0.407). These two individuals have exactly the same profile: they each have a computer that is not connected to the Internet, and have both followed an institutional training in ICT. They have skills in Microsoft Office, and incorporate its tools into their teaching, during which students interact, while getting familiar with the ICT tools used. Nevertheless, these two teachers have no proficiency in Internet nor programming (which is not surprising since they are not connected to the Internet!). The negative components of the projections of these two individuals in the first factorial plan confirm, in turn, the interpretation of the second factorial axis, which is consistent with the one given to the first factorial axis.

Interpretation of the third factorial axis:

The FAMC has led to an absolute inertia of 9.87% for the third factorial axis. The variables that contributed most to the construction of this axis are:

Table 4: Variables with large contributions to the construction of the third factorial axis

Title of variables (Modalities)	**Contribution to Axis 3**
Internet-connected computer (Net_Yes and Net_No)	0,379
Training in ICT (T_ICT_Yes and T_ICT_No)	0,265
Difficulty in using ICT in class (Diffi_ICT_No and Diffi_ICT_Yes)	0,261

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The third factorial axis puts the modalities Net_Yes, T_ICT_Yes and Diffi_ICT_Yes (all three with positive components on Axis 3) in opposition with the modalities Net_No, T_ICT_No and Diffi_ICT_Yes (all negative components in Axis 3).

This opposition informs us about the "Difficulty of using of ICT in the classroom". Indeed, the combination of the modalities Net_No, T_ICT_No and Diffic_ICT_No, is interpreted very easily: a teacher who is not connected to the Internet, and in addition did not follow any training in ICT, will not tend to integrate ICT in class, hence the lack of difficulty in the use of ICT in class. On the other hand, the combination of the modalities Net_Yes, T_ICT_Yes and Diffi_ICT_Yes, informs us about some difficulty in using of ICT in class: Although teachers have received training in ICT, this does not seem to be sufficient to overcome difficulties of classroom management: ICT in education should necessarily be accompanied by training around the pedagogy and didactics of a teaching that integrates ICT.

CONCLUSION AND FUTURE RESEARCH

The methodological approach used in our research to study the integration of ICT in the Life and Earth Sciences (SVT) in secondary school, is completely different from the approaches in the previous studies. Indeed, those approaches are all based on the statistical description, with uni-dimensional statistics, or based on the application of statistical tests of independence for bi-dimensional statistics. Our methodological approach is, however, based on the multi-dimensionality, aiming at identifying and quantifying all important links that result from all the items of our questionnaire.

The Factorial Analysis of Multiple Correspondence (FAMC) applied to the data collected by interviewing 112 teachers has indeed allowed building three factorial axes that accumulate 70% of the information included in all of the responses of the surveyed teachers. The hierarchy induced by the absolute contributions has thus allowed giving each of these areas, according to their order of importance, the following interpretations:

• The first factorial axis, with an absolute contribution of 40%, represents **"The pedagogical benefit and the basic conditions for a successful integration of ICT in education"**

• The second factorial axis, with an absolute contribution of 20%, represents **"Advanced skills in ICT and computing"**

• The third factorial axis, with an absolute contribution of 10%, represents **"The difficulties of using ICT in class"**

Quite unexpectedly, we find that **the interaction of students in class** is the item with the highest relative contribution in building the first factorial axis. This result emphasizes the importance of students' familiarity with their digital environment; this represents a basic condition for a successful integration of ICT. Some training in ICT, preferably an institutional one (as opposed to a self-training), as well as some knowledge of Microsoft Office, seem also to be minimum basic conditions for a successful integration of ICT in education. Thus, the multi-dimensional analysis showed, in one way at least as important as the training of teachers in ICT, the fact of introducing students to ICT tools. This assumes that it is important today to integrate lessons making use of ICT into the curriculum of students, such as algorithms or applications that allow implementing theoretical model simulations. Such ways of teaching will certainly

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contribute to the students' good mastery of the digital environments, as well as their good adaptation to pedagogies integrating ICT in class.

Advanced skills in ICT and computing seem also to have a very positive effect on the integration of ICT. Thus, the items that contributed most to the prominence of this factor are essentially Internet and programming skills, as well as the use of simulation in the classroom. On this basis, the GENIE program perfectly meets these needs through various institutional trainings; so it is one of the political actions undertaken by the Ministry of Education which perfectly results in a successful integration of ICT.

Finally, another key element in the integration of ICT, which was highlighted by the third factorial axis, deals with the training of teachers in the pedagogy and didactics of integrating ICT in class. Indeed, training on ICT tools, whether it is institutional or personal, seems not to be sufficient to overcome classroom management difficulties; the new pedagogical and didactic aspects of classroom management induced by the integration of ICT, must also be taken into account during institutional trainings.

We believe that most of the results of this research can be applied to several other scientific subjects. One of the future views of this research is to conduct the same type of analysis with teachers of mathematics and physical sciences. The comparison of such researches will identify several invariant variables related to the issue of the integration of ICT in Morocco. Such a validation of variables will thus accomplish a breakthrough in the treatment of the issue of the integration of ICT in Moroccan secondary education.

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APPENDIX A:

Questionnaire

I. Personal use of ICT

Q 1 : Do you have a computer at home?

Q 2 : If yes, is this computer connected to the Internet?

Q 3 : What is your daily frequency of Internet browsing?

- Not every day
- Less than one hour per day
- More than two hours per day

II. Availability and use of ICT in teaching

Q 4: Do you have a computer room in your school?

Q 5: What is your degree of use of the following teaching tools?

	Frequently	Not Frequently
Overhead projector		
Audio-Video		
EXAO		
Internet		
Mobile interactive whiteboard		

Q 6: Do you use simulation in your lessons?

Q 7: In which course or activity in the Earth and Life Sciences (SVT in French) do you like to use simulation?

Q 8: Do you use ICT tools for planning your courses?

- Never
- occasionally
- regularly
- always

III. *Pedagogical management of ICT in class*

Q 9: When you use ICT tools in class, does that lead your students to also use them?

Q 10: How do the students interact with a lesson using ICT?

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□ Weakly □ Fairly □ Well □ Very well

Q 11: What are the difficulties encountered during the use of ICT in the classroom?

IV. Trainings and competencies in ICT and computer science

Q 12: Did you follow or profited from training on the use of ICT?

Q 13: If yes, which is the type of this training?

□ Institutional

□ Autonomous

Q 14: What is your degree of mastery of Microsoft Office?

□ Sufficient □ Insufficient

Q 15: What is your degree of mastery of the Internet?

□ Sufficient □ Insufficient

Q 16: What is your degree of mastery of programming?

□ Sufficient □ Insufficient

Appendix B:

Results of the FAMC (with 11 modalities)

Summary of the treatment of the observations

Active valid observations	112
Active observations with missing values	0
Additional observations	0
Total	112
Observations used in the analysis	112

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History of the iterations

Number of iterations	Explained variance		Loss
	Total	Increase	
66[a]	2,532992	,000010	8,467008

a. The process of iteration is interrupted because the test value of convergence has been reached.

Summary of the models

Dimension	Cronbach's alpha	Explained variance		
		Total (eigenvalue)	Inertia	percentage of explained variance
1	,846	4,338	,394	39,433
2	,595	2,176	,198	19,783
3	,086	1,085	,099	9,865
Total		7,599	,691	
Average	,666[a]	2,533	,230	23,027

a. The Cronbach's alpha average value is based on the average eigenvalue.

Measurements of discrimination

	Dimension			Average
	1	2	3	
Computer is connected to the Internet	,008	,062	,379	,149
Difficulties in the use of ICT in class	,006	,025	,261	,098
Use of ICT tools	,907	,004	,009	,307
Participation of students in the use of ICT	,898	,000	,019	,306

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Interactivity of students	,933	,001	,015	,317
Training in ICT	,260	,000	,265	,175
Type of training	,448	,000	,066	,171
Competency in Office	,867	,003	,007	,292
Competency in the Internet	,003	,850	,022	,292
Competency in programming	,000	,408	,007	,138
Use of simulation	,006	,823	,034	,288
Active total	4,338	2,176	1,085	2,533
percentage of explained variance	39,433	19,783	9,865	23,027

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