The core competencies of PhDs

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Abstract: In our knowledge society and economy, doctoral education is increasingly considered as a means to produce knowledge workers to feed the needs of the global employment market. This raises concern about the competencies developed through doctoral training. Surprisingly, only a few studies have addressed this question and most of them are restricted to very limited populations or lack empirical evidences. In this context, we performed a national survey answered by 2 794 PhDs. From the data collected, we built a 111 competencies reference framework organized in 6 main categories. From statistical analysis, we identified a set of 'core' competencies that are shared by doctorate holders (Excel Khi² goodness of fit test, alpha level .05). This study therefore demonstrates that PhDs develop a set of common competencies and delineate its boundaries.

Keywords: doctoral training, competencies, employability, career, survey, PhDs

Introduction

In march 2000, The Lisbon agenda set Europe with the ambitious goal to become 'the most competitive and dynamic knowledge-based economy in the world' (European parliament, 2000). As researchers specifically trained to make significant contributions to frontier knowledge but also as professionals equipped with advanced skills necessary to cope with increasingly complex working situations, PhDs in Europe are expected to fuel the drive towards this goal (Bogle et al. 2010). Thus, policy makers in Europe foster a greater diffusion of PhDs outside the sphere of academic research (Koch Christensen 2005). Similar trends are observed for instance in Australia (Pearson et al. 2011; Neumann and Tan 2011) and in the USA (Khem 2006).

In this context, the focus on doctoral education has shifted from the 'PhD as a product', i.e the contribution to the advancement of knowledge through an original piece of research, to the 'PhD as a process', i.e a training providing the necessary competencies to

become a knowledge worker fitting the needs of the global labour market in a knowledge economy (Park 2005, Buckley et al. 2009).

Although this shift issued in a number of publications concerning changes in the purpose of doctoral education and the means for institutions to implement them (see e.g. Usher 2002; Kendall 2002; Gilbert et al. 2004; Park 2007; Boud and Lee 2008; Mowbray and Halse 2010), fewer publications addressed the question of the competencies actually developed through (as opposed to competencies expected from) doctoral training (Sekhon 1989; Cryer 1998; Borrel-Damian 2009). Moreover, as it is stressed by Buckley and collaborators (2009, p1):

> 'where lists of competencies are proposed, there is little evidence on a theoretical or empirical basis for the choice of these competencies, and the lists appear to have emerged through a process of speculation, or the prior experience of students and faculty, rather than through any coherent analysis'.

This is a critical issue in France where PhDs are not necessarily well-known by companies. Indeed, some companies still merely consider PhDs as experts, lacking a more comprehensive understanding of the wider range of their competencies (Fixari and Pallez 2005; Olivier et al. 2007; Angelier et al. 2009; Grivillers et al. 2010; Baby 2010). This also holds true for PhDs themselves who are not necessarily aware of the competencies they could bring to the global employment market (Fixari and Pallez 2005; Calmand 2010; Grivilliers 2010). Providing both of them with a clearer picture of the competencies developed through doctoral training is therefore likely to facilitate the career development of PhDs in the global employment market.

More recently, Mowbray and Halse (2010) conducted a qualitative survey on PhD students about the competencies they developed during their PhD irrespective of their particular discipline. They used a systematic data analysis procedure, the grounded theory method (Strauss and Corbin 1998), to derive a model of the competencies developed through

the PhD. As they acknowledge it, however, their study relates on data collected from only one university in Australia and includes only 20 PhD students. Furthermore, PhD students might not be the adequate population to study competencies developed during doctoral training since 1) they have not finished it entirely and 2) PhD students might not be well aware of the competencies they have developed (see e.g. Cryer 1998), in particular because they haven't had the opportunity to exercise these competencies in other professional contexts.

In this article, we present the results of a survey on PhDs competencies including 2 794 PhDs who graduated from universities all over France, representing a wide range of disciplines (in Exact Sciences and Humanities) and ages (from 24 to 90 years). A suitable statistical analysis enabled us to determine the 'core' competencies of doctorate holders, i.e. the competencies that have the same probability of being developed through the PhD irrespectively of the discipline, the date of graduation and other factors that will be discussed later. This analysis provides a sound basis to define the outcomes of doctoral education in France in terms of competencies.

Scope

Before discussing the methodology of our study, it is important to first clearly define its scope. The definition of the term 'competency' has long been a matter of debate (for a recent review on this matter, see Abdullah and Sentosa 2012). According to Hoffmann, two main meanings for the term 'competency' can be identified. The first meaning is related to 'outputs', i.e competent performance while the second is related to inputs, i.e. the 'underlying attributes, required of a person to achieve competent performance' (Hoffmann 1999). A similar distinction is proposed by Le Boterf (2011) who emphasize the distinction between 'competencies' and 'competence' claiming that a professional may dispose from a wide range of competencies while not being able to act with competence. According to Le Boterf, 'competencies' constitute the available resources that a professional should be able to suitably

mobilise and combine to adequately address professional situations, i.e. to act competently. The scope of this study is focused on the 'competencies', i.e. the resources available to doctorate holders to act competently.

Method

The main originality of our method is that no competencies were suggested or provided in the survey questionnaire. This way, the participant answers were neither biased nor restricted by a pre-defined list of competencies. Data related to competencies were collected through open-ended questions answered in semi-free text, taking the form of short linguistic expressions separated by commas as in the example above:

> 'Question: please provide a comprehensive list of the competencies you have developed during doctoral training.
> Answer: knowledge in Biotechnology, project management, critical mind, perseverance …'

To quantitatively analyze the data, we first built a competencies reference framework synthesizing all the competencies that had been mentioned by the participants. Answers from the participants were then coded in the terms of this competencies reference framework to perform statistical analysis. In this article, we present the statistical analysis dedicated to the identification of the 'core' competencies of PhDs.

Building of the competencies reference framework

The first step to build the competencies reference framework was linguistic normalization (Arampatzis et al. 2000). The goal of linguistic normalization is to map different but semantically equivalent terms or expressions onto one canonical representative term or expression and therefore account for possible equivalence between natural expressions or terms referring to competencies. For instance, some participants mentioned

their “capacity to manage a project” and others mentioned “project management skills”. Such expressions should be pooled together. Normalization of the data was performed through combining morphological normalization, more usually refered to as “stemming”, with lexico-semantical normalization, to take into account possible synonymy or polysemy between terms or expressions (Arampatzis et al. 2000). A total of 16 000 expressions or terms related to competencies were identified in the survey questionnaires and first pooled into 500 clusters of semantically close expressions. These clusters were inspected by human resources specialists to assess their relevance and consistency and then labeled. When necessary, clusters were split into shorter, more consistent clusters.

In a second step, clusters were hierarchically organized into an ontology to take into account the different levels of precision observed in the data. For instance, one cluster gathered expressions related to ‘communication skills’ in general (for instance ‘ability to communicate’ or ‘good communication skills’) whereas another one gathered more precise expressions related to ‘oral communication skills’ (for instance ‘oral expression’ or ‘eloquence’). This step was performed by human resources experts using a bottom-up procedure inspired from the grounded theory method (Strauss and Corbin 1998). Clusters related to similar competencies (although semantically different) were first grouped into low-level concepts (such as for instance ‘oral communication’). When possible, low-level concepts were grouped into higher level concepts (such as for instance ‘communication’). The process was repeated until no further grouping appeared relevant. The output model is therefore a tree where all the competencies mentioned by participants are represented and organized. The tree obtained through this method is composed of 111 terminal nodes (leafs) organized into 6 major categories, with a maximum of three hierarchical levels. The 6 main categories which emerged from the clustering process are the following:

(1) Knowledge and specialized technical skills. This includes references to specific fields of knowledge (such as Biotechnology, Quantum Physics, Signal Processing, etc.) and to particular techniques and specialized know-how relevant in the particular context of the doctorate (eg. Polymerase Chain Reaction, Latent Semantic Analysis, Grounded Theory method …). Knowledge and specialized technical skills were not separated because the distinction between them was not always clear in the responses such as for instance 'competencies in Biotechnologies', which obviously includes both knowledge and technical skills. Moreover, we do not list all the possible knowledge and technical skills since this list would be potentially infinite. However, we made the distinction between 'mono-disciplinary' and 'pluridisciplinary' knowledge and technical skills.

(2) Transferable competencies that can be formalized. They correspond to competencies which can be used in a wide variety of professional situations and learned through courses. It includes communication skills, project management skills, IT skills, language skills, commercial skills as well as knowledge of the professional environment (academic or industrial), innovation management (including scientific watch and valorization) and administrative management.

(3) Transferable competencies that cannot be formalized. They also correspond to competencies that can be used in a wide variety of professional situations but as opposed to the previous category, these competencies cannot be learned through courses. It includes intellectual capacities, the ability to deal with complex problems (including problem formulation and problem solving), the ability to collaborate (internally or externally), leadership, innovation capacity, a broad vision (including having a broad general knowledge or being able to anticipate), and the capacity to put yourself into question.

(4) Dispositions. This category includes aptitudes and qualities that complement transferable competencies. For instance it includes rigor and creativity, as it is possible to manage a project with rigor, or to be creative while designing a communication media. Twenty-five different dispositions were identified in the collected data.

(5) Behaviors. A total of 32 different behavioral competencies were identified in the collected data. They range from stress management to perseverance including, among others: curiosity, listening to others, resilience, dynamism, patience or honesty.

(6) Meta-competencies. This latest category includes competencies that are useful either to develop one's own pool of competencies or to make a better use of it in professional situations. It therefore includes two different competencies, respectively learning capacity and adaptation capacity.

The competencies reference framework is available in its entirety as online supplemental material.

Data Analysis

To statistically analyze the data, questionnaires were entirely coded in the terms of the competencies reference framework: every particular expression or term in the questionnaire was automatically replaced by a code corresponding to the equivalent competency (node) in the reference framework. This way, it was possible to count the number of occurrences of every node in the tree. The actual indicator we used is the cumulated number of occurrences which is the sum of the number of occurrences of a particular node and of the number of occurrences of all its sub-nodes (childrens). It means that a participant who cited for instance 'oral communication skills' will also be counted as someone who cited 'communication skills' more generally. In the rest of this article, the term 'number of occurrences' will always refer to the cumulated number of occurrences.

The main goal of the statistical analysis was to identify which competencies of the reference framework have the same probability to be developed by PhDs irrespectively of five different factors that could possibly influence the development of competencies during doctoral training, respectively:

(1) The discipline of the doctorate (Table 1)

(2) The date of graduation (Table 2)

(3) Possible activities complementing doctoral training including (as defined by the French Ministry of Higher Education and Research): 1) teaching, 2) consulting for companies, 3) valorization of research outcomes and 4) scientific mediation.

(4) The financing mode of the doctorate including: 1) being specifically paid for realizing the doctorate, 2) realizing the doctorate while exercising another qualified professional activity (e.g. teaching) and 3) realizing the doctorate while exercising another unqualified professional activity.

(5) The source of the financial support including: 1) financial support from the University, 2) financial support related to a particular project (e.g. a project financed by the National Research Agency or the European Union), 3) financial support from both a company and the government (CIFRE) and 4) financial support from other sources.

To study the influence of these factors over the development of competencies during doctoral training, we focused on PhDs answer to the question: 'please provide a comprehensive list of the competencies you have developed during doctoral training'. We then analyzed the distributions of the number of occurrences of each competency in this particular question over the modalities of each of the 5 factors.

More precisely, we used two statistical criteria. The first one was an influence criterion: the Khi² goodness of fit test. This test assessed whether the probability of occurrence of a particular competency was significantly influenced by the different modalities

of a particular factor (for instance whether the probability that a participant mentioned 'oral communication skills' was significantly influenced by its discipline). The Khi² goodness-of-fit test therefore enabled us to compare the distribution of the number of occurrences of each competency according to each factor with respect to the actual distribution of the number of participants according to each same factor respectively.

Each competency was tested with respect to the five different factors (Excel Khi² goodness of fit test, alpha level .05). Independence assumption on the Khi² square test was verified ensuring that the sum of the cells in each contingency table was equal to the number of observations. The expected number of occurrences was also controlled in each modality: if it was inferior to 5, the test was considered as void and the competency was discarded from the set of potential 'core' competencies. If none of the five tests appears significant, the competency was kept as a potential 'core' competency[1], as none of the studied factors appeared to have an influence on its occurrence in participants' answers.

An evaluation of the power of the Khi² goodness of fit test was nevertheless required before declaring these competencies as 'core' competencies. The power of a test is defined as the probability to detect an influence in a particular sample of a population knowing that this influence actually exists in the whole population (in mathematical terms, the power of a statistical test is the complement of the 'beta' error of this test). Therefore, the power values of the tests we performed on the number of occurrences of competencies provide an additional indication as to which a competency could be considered as a 'core' competency of PhDs. For that reason, we calculated the power of the Khi² test for each of the potential 'core' competencies. Only the competencies for which the khi² test's power was superior to 0.7 were kept as 'core' competencies, which means that there was at least 70% of probability to detect an influence in the sampled data if it actually exists in the whole population[2]. They constitute the final 'core' competencies of doctorate holders.

We lastly computed the mean citation rate of each 'core' competency. By definition of the 'core' competencies, this rate is not influenced by any factor considered in this analysis.

Participants

The data used to perform our analysis were extracted from a survey we conducted in 2011 to assess the competencies of PhDs in France and their adequacy with the needs of employers. This survey included three different questionnaires respectively dedicated to PhDs, PhD students and employers that were accessible on an Internet website from the 4th of April to the 29th of August 2011. Overall, 2794 PhDs, 1783 PhD students and 136 employers answered the survey.

All the questionnaires included open-ended questions dedicated to competencies that participants had to answer in free text. The whole amount of text data related to competencies collected through the survey (therefore including data from PhDs but also PhD students and employers) was used to build the competencies reference framework. The statistical analysis presented here was performed only on the data collected from PhDs. The critical point with respect to the results presented here is therefore the representativeness of the PhDs sample.

All disciplines listed by the French 'Research Center on Qualification' (Calmand and Giret 2010) were represented in the PhDs sample. An additional category was considered in our survey: participants who selected more than one discipline where classified as 'Multidisciplinary'. The distribution of the PhDs sample with respect to disciplines is presented in table 1.

To prevent any statistical bias, samples were weighted to fit the actual distribution of PhDs across disciplines in France. As no data concerning the actual distribution across discipline of the whole population of PhDs in France were available, we used, in a first approximation, the distribution across disciplines of PhDs who graduated in France in 2004 (Calmand and Giret 2010). As the 'Multidisciplinary' category was not considered by the

Cereq, PhDs from this category were not considered in the weighting process and were not weighted in the statistical analysis.

Ages of the participating PhDs range from 24 to 90 old years with a 32 years old median age. The distribution of participants with respect to the date of their graduation (expressed in number of years prior to the 1st of January 2011) is presented in table 2.

To control the consistency of our sample with respect to the size of institutions across the national territory, we compared the total number of PhD students in 2009-2010 in 25 institutions as provided by the French Ministry of Research and Higher Education (2010) with the sample size of PhDs in our survey in these 25 institutions respectively. Except for the university 'Pierre and Marie Curie', which was a partner of the project and appeared as an outlier (Cook's d = 5.5), the regression analysis showed a significant correlation (p value < 10^{-4}, $R^2 = 0.7$), therefore showing a consistent coverage of institutions at the national level.

Results

The pool of 'core' competencies of PhDs

The competencies of the reference framework that have been classified as 'core' competencies of PhDs by the statistical analysis are provided in table 3. The level of the competency in the hierarchy of the competencies reference framework is mentioned. For each competency, the percentage of doctorate holders mentioning it as developed through doctoral training is also provided (mean citation rate). By definition of the 'core' competencies, this percentage does not significantly depend (alpha level .05) on the discipline of the doctorate, the date of graduation, the possible complementary activities occurring during doctoral training, the situation of the doctorate holder during doctoral training and the source of financial support (as detailed in the 'Identification of the core competencies' section). The minimum value of the statistical power of the Khi² test for each competency over the five

different factors is also mentioned (Power).

The first result is that doctoral training, whatever the context in which it occurred, enables the development of competencies in all the six main categories referenced in the framework (level 1). Curiously enough, category A, 'Knowledge and technical skills', is not the most frequently cited category.

The most frequently cited category is 'Transferable competencies that can be formalized' (B) mentioned by 79% of PhDs. In this category, communication skills are most frequently cited (62%) including both written and oral communication skills as core competencies. 'Project management' appears in second position (42%) and includes time management as a core competency. In third position 'Innovation management' is cited by 21% of PhDs and includes scientific watch as a core competency. Lastly, 'Languages' is mentioned by 11% of PhDs.

The second most frequently cited category is 'Transferable competencies that cannot be formalized' (C) mentioned by 68% of PhDs. In this category, cognitive abilities are the most frequently cited (46%). The ability to collaborate appears in second (23%) and includes the ability to work in a team. Finally, the ability to deal with complex problems is mentioned by 18% of PhDs.

Category D, 'Dispositions' appears in third position, with a 64% citation rate close to category C. In this category, three core competencies have been identified: autonomy, with 30% of PhDs mentioning it, rigor (22%) and creativity (10%).

'Knowledge and technical skills' (A) appears only in fourth position with 44% of PhDs mentioning it and includes mono-disciplinary (by opposition to pluri-disciplinary) knowledge and technical skills as a core competency with a 42% citation rate.

'Behaviors' (category E) were almost as frequently cited as 'Knowledge and technical skills' with a 42% citation rate. Although many behaviors have been identified through the

survey, ‘Perseverance’ was the only one not to be affected by any factors considered in the statistical analysis. It was mentioned by 19% of PhDs.

Finally, ‘Meta-competencies’ were cited by 19% of PhDs. They include ‘capacity for adaptation’ as a core competency mentioned by 16% of PhDs.

Comparison with the international literature

To compare our results with the literature, we translated the competencies mentioned in two other articles dedicated to the outcomes of doctoral training (Cryer 1998; Mowbray and Halse 2010) into the terms of our competencies reference framework. These articles were selected because they share the same goal as our study: to provide an overview of the competencies shared by PhDs irrespectively of the discipline or the particular context of doctoral education. The results of this comparison with respect to the ‘core’ competencies identified in our study are presented in table 4.

Almost all the ‘core’ competencies identified in our survey were mentioned in the two other articles. Two identified ‘core’ competencies were not mentioned in any of the other studies, respectively ‘Languages’ and ‘Rigor’. The reason why ‘Languages’ is missing in the other studies lies in the fact that they were performed in English speaking countries where practicing English therefore correspond to competencies in ‘Communication’ more than in “Languages’. The case of ‘Rigor’ is more delicate to interpret. The reason why this competency was not mentioned explicitly in the other study may be because it was considered either as a part of cognitive skills or as a part of research knowledge and technical skills. Another difference is the case of ‘Ability to work in a team’. Actually, this competency is mentioned by Cryer (1998) but, in her opinion, it concerns only ‘students working on group projects, which is most common in the sciences’. What our study reveals is that if, indeed, not all PhDs had the occasion to develop team working (this competency was mentioned by only

15% of PhDs in our study), there is no significant difference in France between PhDs in Science and in the Humanities with respect to this matter.

Reciprocally, four competencies were mentioned in both the other studies while not being identified as 'core' competencies in our results: 'Financial management', 'Critical thinking', 'Resilience' and 'Ability to find solutions'. "Financial management" and "Resilience" were not mentioned frequently enough by the participants to perform reliable statistical analysis on their number of occurrence. It is therefore an open question as to whether they can be considered as 'core' competencies of PhDs. Nevertheless, 'Resilience' is close to 'Perseverance' which has been identified as a 'core' competency. 'Critical thinking' and 'Ability to find solutions' have indeed been mentioned by participants in all disciplines, but they were significantly more frequently mentioned by participants in 'Exact' Sciences than in the Humanities and, for that reason, were not identified as 'core' competencies.

Our study also provides a quantitative measure indicating how frequently each competency has been mentioned by PhDs (the so-called 'Citation Rate'). This measure should not be confused with the actual frequency with which competencies are developed during doctoral training. Indeed, as no competencies where provided in the survey questionnaire, participants may have forgotten to mention some of the competencies they developed during doctoral training. For that reason, the 'Citation rate' is likely to underestimate the actual frequency to which competencies are developed during doctoral training. To further examine this question, we compared our results with the study realized by Sekhon (1989) on PhDs in mathematics. In this latest study, participants were provided a set of competencies, therefore preventing participants from forgetting them. For each competency, they had to notify whether their doctoral training enabled them: 1) to develop it, 2) to develop it to an extent or 3) did not enable them to develop it. Since, in our study, there is no distinction between 'developed' and 'developed to an extent', we used the sum of the first and second choice

answer rates in Sekhon's study to make the comparison with our citation rates through a linear regression.

The way competencies are expressed differs in both studies. Nevertheless, we identified seven competencies that can reasonably be matched between the two studies. They are reported in table 5. As three different competencies in Sekhon (1989) could be included in our item 'Monodisciplinary knowledge and technical skills', we used the mean of their respective answer rates. All the considered competencies belong to the pool of 'core' competencies identified in this study. By definition, the citation rates of these competencies do not depends on the discipline. They can therefore be compared to the answer rates obtained by Sekhon (1989) on PhDs in Mathematics.

The result of the linear regression between the answer rates from Sekhon (1989) and the citation rates from our study is shown in figure 1. As expected, answer rates measured in the study by Sekhon (1989) are higher that the citation rates measured in our study. The average difference is 37%, as determined by the intercept of the regression analysis. However, citation rates from our study appeared linearly correlated with the answer rates from Sekhon (1989): the regression analysis shows a significant coefficient of determination $R^2 = 0.68$, significant at the .05 alpha level of confidence. It corroborates that the relative differences observed between our competencies' citation rates provide reliable information about the relative extent to which these competencies are developed during doctoral training. Moreover, the equation of the trend curve derived from the linear regression analysis ($y = 1.25x+37$), applied to our citation rates, can be used to provide an estimation of the actual extent to which our 'core' competencies are developed during doctoral training.

Interestingly enough, this gap between the spontaneous citation rates in our study with respect to the answer rate from the Sekhon (1989) study (where competencies were provided in the questionnaire) demonstrates how difficult it might be for a PhD to provide a

comprehensive overview of the competencies developed through doctoral training. It therefore demonstrates the interest to clarify the outcomes of doctoral training in terms of competencies.

Apart from a good overall correlation, the comparison between our study and the results obtained by Sekhon (1989) also shows interesting second order differences. In particular, the two competencies that deviate the most from the trend curve are 'Autonomy' and 'Ability to work in a team', respectively showing a +17% positive deviation and a -19% negative deviation. It means that, taking into account the methodological differences between the two studies and with respect to our results, PhDs surveyed by Sekhon (1989) more frequently developed autonomy and less frequently developed team working. This observation appears rather self-consistent, providing that the less you work with others, the more you need to develop autonomy. It is an open question whether this observation is related to differences between French and Australian doctoral training or whether it is related to the fact that the study by Sekhon (1989) was realized more than twenty years prior to our study.

Discussion

With respect to the literature, the main originalities of our method to derive the core competencies of PhDs are the following:

(1) It is based on a quantitative analysis of data collected from a wide range of doctorate holders, compared to Mowbray and Halse (2010) who performed qualitative analysis over a much more restricted panel of PhD students, and to Cryer (1998) where competencies emerged from a mere, although soundly argued, speculation.

(2) So as not to influence nor restrict the participants' answers, no competencies were provided in the survey questionnaire, compared with Sekhon (1989).

(3) Five different factors influencing the development of competencies during doctoral training were studied, whereas in Borrell-Damian (2009) and Mowbray and Halse (2010), only the discipline was considered and in Sekhon (1989), only doctorate holders in Mathematics were surveyed.

The results presented here are therefore strongly grounded on a firm empirical base. In particular, as a main difference with other studies, the identified core competencies have been tested statistically to verify that they have the same probability to be mentioned by PhDs as competencies developed through doctoral training whatever the particular conditions of doctoral education (i.e irrespectively of the five 'factors' mentioned in the 'Identification of the core competencies of PhDs' section). In this sense, this work provides the first empirically and statistically assessed pool of competencies developed through doctoral training.

This does not mean that competencies developed through doctoral education are restricted to this pool. Actually, 105 out of the 111 competencies constituting the third level of the competencies reference framework have been mentioned by at least one PhD as being developed during doctoral training. But, except for the 'core' competencies presented here, these competencies could not be generalized to the whole population of PhDs, either because we detected an influence by one of the five factors considered in our study or because the competency was not sufficiently mentioned by participants to perform a reliable statistical analysis.

Overall, the current analysis on PhDs competencies in France shows a great overlap with the international literature on that matter. This currently argues in favor of an homogeneity between doctoral training outcomes in western countries. However, the existing literature is currently limited to the UK and Australia, and methodological differences may have hidden second order differences. Therefore, we expect this study to trigger further

investigations in other countries using compatible methodologies in order to make more detailed comparisons.

onclusion

The main conclusion that can be drawn from this study is that, although doctoral training experience can be very different from one PhD to another (depending on many factors such as, for instance, discipline or date of graduation), a substantial part of its outcomes, in terms of competencies, remains constant. This constant part, statistically established and presented here as a set of 'core' competencies, is not limited to knowledge and technical skills. It includes transferable competencies, some of which are not likely to be learned through courses but mainly through practical experience. The PhDs pool of core competencies also includes dispositions, behaviours, and meta-competencies (particularly the ability to adapt one's pool of competency to different professional situations and contexts). In the framework of the 'as a process' approach to doctoral training (Park 2005), this study therefore provides a rationale to justify considering the PhD as a legitimate and relevant object of study, while delineating its boundaries.

This should not overshadow the fact that the outcomes of doctoral training are far from being restricted to this pool of competencies. As it is emphasized by Craswell (2007), 'diversity is the hallmark of higher degree research students'. Indeed, in our study, almost all competencies of the reference framework (105 out of 111 competencies) have been mentioned by PhDs. The pool of 'core' competencies therefore represents only ¼ of all the competencies that can be developed through doctoral training, depending on the discipline, the date of graduation, the complementary activities, the mode and the source of funding.

Furthermore, the doctoral experience cannot be reduced to a mere list of competencies or skills (Gilbert et al. 2004, Craswell 2007, Mowbray and Halse 2010). Contrarily to 'atomistic' descriptions of doctoral experience outcomes through lists of competencies, some

recent studies propose a holistic perspective to that question by analysing metaphors used to describe doctoral experience or doctoral candidates (Baptista and Huet 2012, Bégin and Gérard 2013).

Notwithstanding the interest of holistic approaches to doctoral outcomes, competencies, as they are defined and expressed in this article, are central in the recruitment process, from the résumé selection (Bright and Hutton, 2000) to the final decision (Roberts, 1997). They constitute a common vocabulary between doctorate holders and employers. We therefore consider them as a suitable practical tool to help PhDs valuing their doctoral experience in front of recruiters, and to further analyse and highlight the adequacy between doctoral trainings and the needs of the employment market.

Notes

1. Actually, we also considered the size of the effect as defined in Cohen (1988). According to him, if its size is inferior to 0.3, the effect can be considered as small. We therefore considered only effects which sizes were superior to 0.3.
2. Consistently with the preceding note, we calculated the Khi2 test power setting the size of the effect to 0.3.

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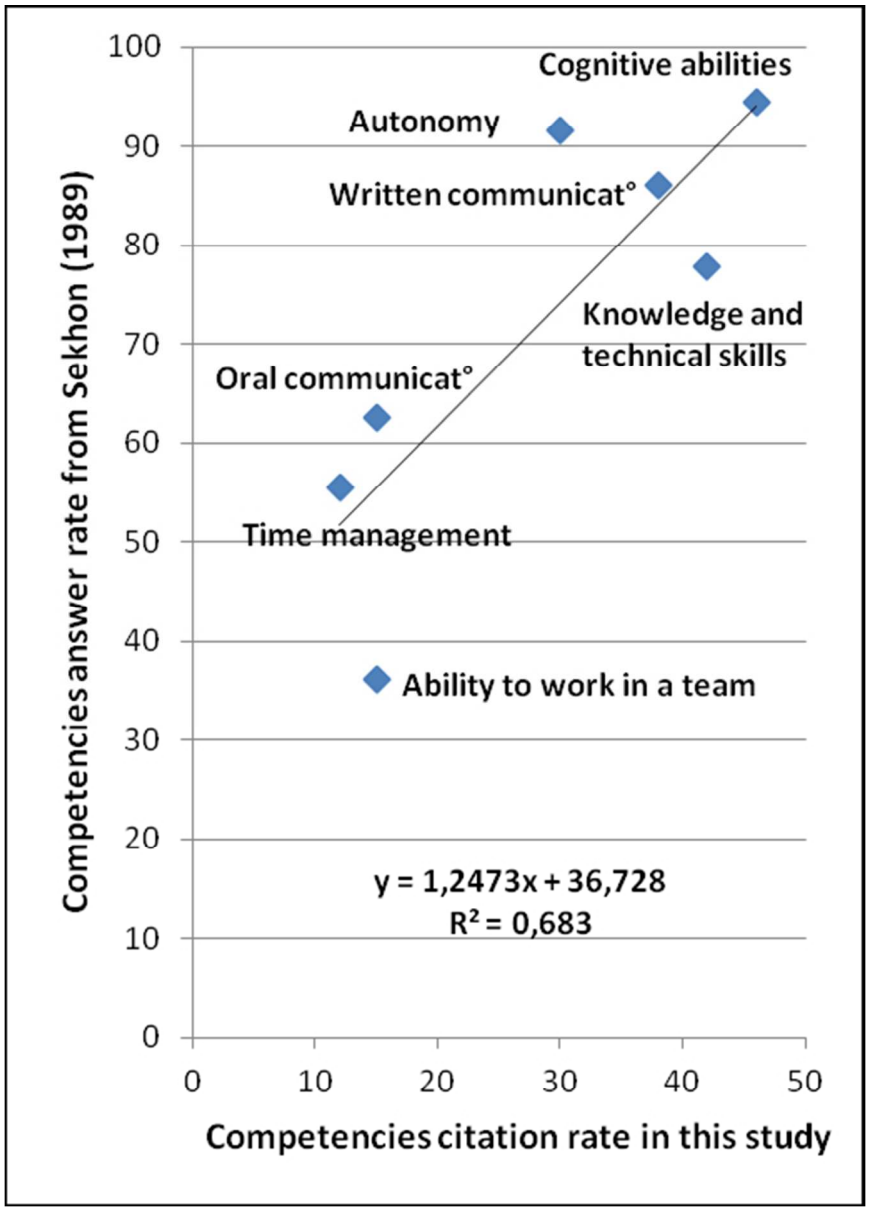

Figure 1: Comparison between the competencies citation rate from Sekhon (1989) and from the current study.
182x254mm (72 x 72 DPI)

Table 1: distribution of the PhDs sample across disciplines

Discipline	Distribution
Mathematics and Physics	10%
Engineering, Mechanics, Electronics & Computing	17%
Chemistry	11%
Earth & Life Sciences	37%
Laws, Economics & Management	4%
Literature & Human Sciences	10%
Multidisciplinary	11%

Table 2: distribution of the PhDs sample with respect to the graduation's antecedence

Graduation antecedence	Distribution
Less than one year (including graduations in 2011)	24%
Between one and three years	26%
Between three and ten years	38%
Between ten and thirty years	11%
More than thirty years	1%

Table 3: the PhD's pool of core competencies

Competency	Level	Power	Mean Citation rate
A. Knowledge and technical skills	1	1.00	44%
A.1. Mono-disciplinary knowledge and technical skills	2	1.00	42%
B. Transferable competencies that can be formalized	1	1.00	79%
B.3. Communication	2	1.00	62%
B.3.a. Written communication	3	1.00	38%
B.3.b. Oral communication	3	0.93	15%
B.5. Innovation management	2	1.00	21%
B.5.a. Scientific watch	3	0.98	17%
B.6. Project management	2	1.00	42%
B.6.d. Time management. planning	3	0.86	12%
B.7. Languages	2	0.87	11%
C. Transferable competencies that cannot be formalized	1	1.00	68%
C.3. Cognitive abilities	2	1.00	46%
C.4. Ability to deal with complex problems	2	1.00	18%
C.5. Ability to collaborate	2	1.00	23%
C.5.a. Ability to work in a team	3	0.94	15%
D. Dispositions	1	1.00	64%
D.2. Rigor	2	0.99	22%
D.16. Creativity	2	0.8	10%
D.24. Autonomy	2	1.00	30%
E. Behaviors	1	1.00	42%
E.8. Perseverance	2	0.98	19%
F. Meta-competencies	1	0.99	19%
F.1. Capacity for adaptation	2	0.96	16%

Table 4: comparison between the pool of core competencies derived from our analysis and the other studies on the competencies shared by PhDs. Legend: '*'= mentioned as shared by all PhDs; '-' = not mentioned; (*): mentioned as depending on the discipline

Competency	Level	Cryer (1998)	Mowbray and Halse (2010)
A. Knowledge and technical skills	1	*	*
A.1. Mono-disciplinary knowledge and technical skills	2	*	*
B. Transferable competencies that can be formalized	1	*	*
B.3. Communication	2	*	*
B.3.a. Written communication	3	*	*
B.3.b. Oral communication	3	*	*
B.5. Innovation management	2	*	*
B.5.a. Scientific watch	3	*	*
B.6. Project management	2	*	*
B.6.d. Time management. planning	3	*	*
B.7. Languages	2	-	-
C. Transferable competencies that cannot be formalized	1	*	*
C.3. Cognitive abilities	2	*	*
C.4. Ability to deal with complex problems	2	*	*
C.5. Ability to collaborate	2	(*)	*
C.5.a. Ability to work in a team	3	(*)	*
D. Dispositions	1	*	*
D.2. Rigor	2	-	-
D.16. Creativity	2	*	*
D.24. Autonomy	2	*	*
E. Behaviors	1	*	*
E.8. Perseverance	2	*	*
F. Meta-competencies	1	*	*
F.1. Capacity for adaptation	2	*	*

Table 5: the seven competencies selected to perform a comparison with the study designed by Sekhon (1989), expressed in the terms of our competencies reference framework and in the original terms from Sekhon (1989)

Competencies Reference Framework	Sekhon (1989)
Cognitive abilities	Highest intellectual caliber
Monodisciplinary knowledge and technical skills	Fluency in a broad range of mathematical methods ; Up-to-date knowledge of development in the field ; Effectiveness in mathematical modeling
Time management	Ability to get things done on time
Oral communication	Good oral communication skills
Written communication	Good written communication skills
Ability to work in a team	Ability to work as a member of a research team
Autonomy	Ability to work unsupervised and undirected

Figure 1. Comparison between the competencies citation' rate from Sekhon (1989) and from the current study.

The complete Competencies Reference Framework derived from the study

- A-Knowledge and technical skills
  - A.1-Monodisciplinary
  - A.2-Pluridisciplinary
- B-Transferable competencies that can be formalized
  - B.1-Knowledge of the professionnal environment
    - B.1.a-Knowledge of the academic environment
    - B.1.b-Knowledge of the industrial environment
  - B.2-Professionnal conduct
    - B.2.a-Regulation
    - B.2.b-Ethics
    - B.2.c-Safety
  - B.3-Communication skills
    - B.3.a-Written communication
    - B.3.b-Oral communication
    - B.3.c-Graphic communication
    - B.3.d-Popularization
    - B.3.e-Pedagogy
    - B.3.f-Mastery of communication tools
  - B.4-IT skills
  - B.5-Innovation management
    - B.5.a-Scientific watch
    - B.5.b-Research valorization
  - B.6-Project Management
    - B.6.a-Project building
    - B.6.b-Faisability study
    - B.6.c-Funding generation
    - B.6.d-Time management, planning
    - B.6.e-People management
    - B.6.f-Financial management
    - B.6.g-Quality management
    - B.6.h-Conflict management
    - B.6.i-Risks management
    - B.6.j-Reporting
    - B.6.h-Result orientation
  - B.7-Languages
    - B.7.a-Written languages
    - B.7.b-Oral languages
  - B.8-Commercial skills
    - B.8.a-knowledge of the products
    - B.8.b-Understanding of customer's needs
    - B.8.c-Canvassing
    - B.8.d-Negociating

        - B.8.e-Interacting with customers
        - B.8.f Promoting products
    - B.9-Administrative management
- C-Transferable competencies that cannot be formalized
    - C.1-Lateral thinking
        - C.1.a-General knowledge
        - C.1.b-Global understanding
        - C.1.c-Capacity to anticipate
        - C.1.d-Understanding of industrial issues
    - C.3-Cognitive abilities
        - C.3.a-Analysing
        - C.3.b-Synthesizing
        - C.3.c-Ability to grasp the abstract
        - C.3.d-Understanding
        - C.3.e-Critical thinking
    - C.2-Capacity for innovation
    - C.4-Complex problems management
        - C.4.a-Ability to identify and formulate problems
        - C.4.b-Ability to find solutions
        - C.4.c-Ability to intepret results
    - C.5-Ability to collaborate
        - C.5.A-Ability to work in a team
        - C.5.b-Ability to develop and maintain a network of collaborators
        - C.5.c-Ability to work in multicultural environments
    - C.6-Leadership
        - C.6.a-Ability to take decisions
        - C.6.b-Ability to motivate collaborators
        - C.6.c-Ability to delegate responsabilities
        - C.6.d-Ability to take the upper-hand
        - C.6.e-Ability to take responsabilities
    - C.7-Ability to question oneself
- D-Dispositions
    - D.1-Method
    - D.2-Rigor
    - D.3-Pragmatism
    - D.4-Meticulousness
    - D.5-Ability to make propositions
    - D.6-Ability to persuade
    - D.7-Clarity
    - D.8-Open-mindedness
    - D.9-Initiative
    - D.10-Being observant
    - D.11-Vigilance
    - D.12-Focussing
    - D.13-Efficiency
    - D.14-Versatility
    - D.15-Ingenuity
    - D.16-Creativity
    - D.17-Depth
    - D.18-Capacity to think clearly

- D.19-Accuracy
- D.20-Originality
- D.21-Perceptiveness
- D.22-Clear-headedness
- D.23-Correctness
- D.24-Autonomy
- D.25-Dexterity

- E-Behaviors
  - E.1-Audacity
  - E.2-Self-reliance
  - E.3-Sense of hearing
  - E.4-Interpersonal skills
  - E.5-Tolerance
  - E.6-Understanding
  - E.7-Openness to others
  - E.8-Perseverance
  - E.9-Commitment
  - E.10-Self-confidence, stress management
  - E.11-Resilience
  - E.12-Patience
  - E.13-Empathy
  - E.14-Diplomacy
  - E15-Dynamism, enthousiasm
  - E.16-Modesty
  - E.17-Curiosity
  - E.18-Honesty
  - E.19-Reliability
  - E.20-Charisma
  - E.21-Ambition
  - E.22-Availability
  - E.23-Punctuality
  - E.24-Service-minded
  - E.25 Assiduousness
  - E.26-Humour
  - E.27-Respect of authority
  - E.28-Hygiene
  - E.29-Maturity
  - E.30-Sincerity
  - E.31-Ability to conciliate
  - E.32-Self-control
  - E.33-Dreamer
  - E.34-Abnegation
- F-Meta-competencies
  - F.1-Ability to learn
  - F.2-Adaptability