Scientific Skills in Mexican Graduate Students: Curriculum, Mentoring and Institutional Support

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Received: June 6, 2016 Accepted: June 22, 2016 Online Published: June 22, 2016

doi:10.5430/ijhe.v5n3p70 URL: http://dx.doi.org/10.5430/ijhe.v5n3p70

Abstract

In our research we examined the the relationship between the perception of scientific skills acquisition in Mexican graduate students with their awareness of scientific competences considered in the curriculum, mentoring practices and availability of institutional resources for conducting research. The study involved a conventional sample of 147 graduate students (*M* age=28, *DS*= 6.52 years) in natural sciences and engineering from public higher education institutions from a northwest state of Mexico. The results of multiple linear regression show that the variables studied are significantly associated with the perceived acquisition of scientific skills during the program, the importance of scientific competence in the curriculum, mentoring practices and available resources for research. Implication for graduate programs are discussed in light of the results.

Keywords: Curriculum, Graduate, Mentoring, Scientific skills

1. Introduction

1.1 Introduce the Problem

In the era of the knowledge society, economic and social developments are grounded on the availability of a highly specialized human capital. Countries aspiring to prosper need to implement research and education policies that enhance the generation of leading edge knowledge and technology. These two factors are recognized as key elements for the global competitiveness for both companies and nations alike (Organization for Economic Co-operation and Development [OCDE], 2007).

The knowledge base of a country is defined as the ability to create innovative ideas, thoughts, processes, and products to translate them into technologies and practices that contribute to economic and social welfare (Huggins & Izushi, 2007; López, 2005). For the Scientific and Technological Consultative Forum ([FCCyT], 2006) knowledge-based development must seek the welfare and quality of life for everyone.

Social and economic development require actions aimed at training high-level human resources that may contribute to the generation, transference and social appropriation of science and technology (FCCyT, 2008). Thus, higher education institutions should ultimately develop competencies in graduate students that include the integration of knowledge, skills and attitudes that are able to generate scientific information, manage resources for research, and disseminate its results (Valdés, Vera, & Carlos, 2012).

In this context, graduate programs must meet the economic, political and technological demands. They need to be effective in producing top-level human resources, who are capable to contribute to the solution of social, environmental and economic problems (Lanvin & Fonstad, 2009). The United Nations Educational, Scientific and Cultural Organization ([UNESCO], 2009) views higher education, as the foundation for building an inclusive and diverse knowledge society. Besides, UNESCO suggests increasing research and innovation through partnerships between public and private sectors that give mutual benefits to both.

In México, the National Council for Science and Technology ([CONACYT], 2012), a federal institution in charge of policies regarding scientific and technological development, recognizes that graduate programs are primarily responsible for the formation of highly specialized researcher. However, graduate students represent only the 7% of the total of students in the Mexican educational system. Moreover, from the total of graduate students only 8% are enrolled in a doctoral program (National Association of Universities and Higher Educations Institutions [ANUIES], 2008).

Two key concepts in achieving global competitiveness are functionality and pertinence. The first one refers to the promotion of links between companies and universities, to promote innovation by training highly qualified human resources (De la Orden, Asencio, Biencinto, González, & Mafokosi, 2007). The second one has to do with focusing on social needs and existing resources (National Council for Science and Technology/ Undersecretary of Higher Education, 2012).

Our study took place in the northern state of Sonora, the latest national census of 2010 reported there were approximately 25 thousand professionals with graduate degrees. These figures placed the region in fifth place nationally regarding the ratio of the population with a graduate degree in Mexico (FCCyT, 2011). However, the graduate degree's impact on regional development has not been fully documented. In fact, some problems in the quality of graduate programs have been reported. For example, there are a limited number of programs with duly authorized faculty, few programs are recognized in the roster of excellence (PNPC, for its initials in Spanish), and many of those programs are unrelated to scientific or technological fields (Vera & Valdés, 2013).

1.2 Explore Importance of the Problem

Despite the importance of training doctors in the areas of engineering and science to achieve social and economic development based on knowledge opportunities in Mexico, the study about programs that are dedicated to the training of these professionals is still emerging. Analysis of the existing literature on the subject shows that, generally, investigations are carried out from a frame with a process-product approach and focus on training programs for researchers in the field of education.

Studies on the postgraduate in Mexico are limited, usually, within a process-product approach and focus on indicators such as terminal efficiency and income of graduates of the National System of Researchers, among others (Álvarez, Gómez, & Morfín, 2012; Aquino, 2011; FCCyT, 2011; Jiménez, 2010; Luchilo, 2009), which although they are useful for evaluating the effectiveness of graduate programs, they provide little information about particularities of the organization and operation of graduate programs affecting the quality of learning in students. In Mexico, and even internationally, studies are performed less frequently about postgraduate, particularly in the areas of engineering and natural sciences, addressing the influence of aspects of the curriculum, relations between actors in the educational process (researchers- students), and the management on the quality of the teaching-learning students graduate programs in the country (Mendoza & Jiménez, 2009; García & Barrón, 2011; Rodríguez, 2011; Valdés, Estévez, & Vera, 2013).

1.3 Describe Relevant Scholarship

1.3.1 Issues related to the Curriculum

In Mexico, some research has focused on curriculum processes related to the formation of competencies in graduate students. In this perspective, studies often address teacher-student relationships (De la Cruz & Abreu, 2009), ethical practices of teachers (De la Cruz, Díaz-Barriga, & Abreu, 2010), mentoring practices (Fresan, 2002; Moreno, 2007) and graduate teaching models (Moreno & Romero, 2011).

In general, these studies underline the importance of establishing links between researchers' interests and social needs that would facilitate the identification and solution of problems in a given context (pertinence). Hence, curriculum development in graduate programs faces great challenges, as it requires a balance between theory and practice. In fact, approval of graduate programs in Mexico, usually requires an analysis of social, political and economic forces in the vicinity of the institution (Buitrón, 2002).

These studies, in general, recommend coordination of educational actors and program aims through explicit activities that are synergic to synchronize and focus efforts of both students and teachers. Therefore, science's curriculum development should ensure interaction and exchanges among the different educational actors, ensuring diverse methodological approaches and theoretical perspectives towards an explicit common goal. Graduate programs need syllabus that makes explicit the relationship between the student and the teacher. There is a need of guides and documents that provide greater clarity and consistency between the established curriculum and the teaching practices that actually takes place on the day-to-day basis (Guerra, 2006).

1.3.2 Mentoring Practices

The research of mentoring has been conducted in three major areas (youth, academic and workplace), having the mentoring relationship as a focus (Eby, Allen, Evans, Ng, & DuBois, 2008). Academic mentoring can be associated with a wide range of positive outcomes for protégés as a way to improve the academic adjustment, retention, and success of college students (Johnson, 2007). Jacobi (1991), typifies the apprentice model of education on academic and non-academic mentoring. The academic mentoring is referred when a faculty member imparts knowledge, provides support and offers guidance to a student in a classroom performance; it also tends to target student retention and adjustment to college life. The non-academic mentoring is referred to personal problems and identity issues. Both types of mentoring may facilitate psychological adjustment and foster a sense of professional identity (Austin, 2002).

Researchers have investigated mentoring relationships within academic settings with disciplinary roots in education and counseling psychology. Some of these mentoring relationships develop spontaneously between two persons, whereas others originate in formal mentoring programs in community sceneries, on college campuses or organizations (Allen & Eby, 2007). The mentoring relationship is given between a more experienced person (a mentor) and a less experienced individual (a protégé), where the primary goal of mentorship is the growth and development of the protégé. Mentors are distinctive from other potentially influential people such as role models, advisors, teachers, supervisors and coaches (Eby, Rhodes, & Allen, 2007)

In the international context, there is a wide range of research methods for academic mentoring, from narrative reviews (Zimmerman, Bingenehimer, & Behrendt, 2005), to quantitative reviews (Dorsey & Baker, 2004; Sambunjak, Straus, & Marusic, 2006). These studies have focused on mentoring phases, alternatives forms of mentoring and diversified mentoring relationships.

It is important to mention, that in Mexican higher education policy, mentoring has been equated to counseling and tutoring the student. Tutoring involves advice on academic issues. Also, it demands counseling the student on personal and family issues. Graduates' mentoring guides their students' development in independent research through dialogue and by modeling appropriate research behavior (Pearson & Brew, 2002).

In fact, tutors are expected to encourage the development of academic and social-emotional skills and to facilitate academic and professional success (De la Cruz et al., 2010). Actually, some studies have indicated that this activity increases completion rates and avoids drop out in some programs (De Del Castillo, 2007; Torres, 2011). However, there is still a need to explore the student's views on these activities that clearly make blurring borders between academic and personal issues.

1.3.3 Resources for Developing Research

Scientific and technological research requires considerable resources and demand significant investments from both Governments and companies alike. Materials, equipment, gear and many other essential are sometimes limited due to some budget constrictions and departmental managerial decisions (Galaz & Gil, 2009). Thus, it is important to explore the views of students on the availability of such resources for their training and the successful completion of their research (Denison, Hart, & Kahn, 1996).

Institutional support is considered positively associated to the development of scientific skills in students as well as the resources and support that is given to research activities (CONACYT, 2012; Felisberti & Sear, 2014). This affects efforts, commitment, skills development and results of graduate production, transfer and commercialization of knowledge (Jin & Zhong, 2014; Yusuf, 2006).

Many studies in Mexico have documented researchers' complaints regarding resources and support (Flores, Ordoñez, & Viramontes, 2015; Metlich, 2009; Munevar & Villaseñor, 2008; Topete, Bustos, & Bustillos, 2012). However, few studies address the perceptions of their students about this topic.

1.4 State Hypotheses and Their Correspondence to Research Design

Considering the lack of research in the country about the quality of training processes in graduate programs in the areas of science and technology, our study investigates the perceptions of graduate students enrolled in Biology and Engineering master's and doctoral programs from three public higher education institutions regarding their acquired scientific skills. We collected their views over the influences that the curriculum, mentoring practices, and existing institutional support have on the development of their scientific skills. We also were interested in the implications of such views to the implementation of policies and best practices in graduate programs.

2. Method

2.1 Participant (Subject) Characteristics

A total of 147 postgraduate students participated in the study. 77 (52%) from natural science and 70 (48%) of engineering. The students were from three different public higher education institutions in the state of Sonora; which borders the state of Arizona in the US. They all volunteered to respond three pencil and paper questionnaires. From these, 80 (54%) were male and 67 (46%) female. Their average age was 28 years (*DS* = 6.52 years).

2.2 Measures and Covariates

Importance and acquisition of scientific of scientific skills. This scale was developed by Valdes et al. (2012), to assess three types of skills related to scientific practice: (a) generic professional skills, for example *English language proficiency* (α= .88, 11 items); (b) skills of generation and dissemination of knowledge, for example *statistical data analysis* (α= .86, eight items) and (c) resource management competencies, for instance *the ability to develop a research projects to compete for funds* (α= .84, seven items).

For both, importance and acquisition perceptions, there was a seven-point Likert type. For importance response scale ranging from 0 (*Not important*) to 6 (*Very important*) and for acquisition ranging from 0 (*nothing developed*) to 6 (*fully developed*). An exploratory factorial analysis through *Maximum Likelihood* method and rotation *Oblimin* yielded a three-dimensional structure as proposed by the authors (*KMO*= .88; X^2= 474.23, *p*< .001; 62.1% explained variance).

Perceived resources for research. This instrument developed by Valdes (2013) was based on the innovation model proposed by Albornoz, Carneiro and Firmino da Costa (2006). This instrument explored the student's perception on the availability of resources they had access in in terms of facilities, materials, assistants, manuals and information sources. For example: *laboratories equipment, materials and travel su*pport. Response scale was a seven-point Likert scale with values from 0 (*totally agree*) to 6 (*strongly disagree*).

An exploratory factorial analysis through the *Maximum Likelihood* method and rotation *Oblimin* yielded a unidimensional structure (*KMO*= .80; X^2= 132.23, *p*< .001; 52.1% explained variance). Cronbach's Alpha was .82.

Mentoring support. We developed a scale based on De la Cruz's (2007) schema to assess mentors in two essential domains. The personal domain, which implies support and orientation regarding to personal relationships and other non-academic problems, for example: *providing help in coping with problems with family and friends* (α= .71, five items. The academic domain, involves make-decision guidance and support for solving issues related their formation as scientists, for example *helping the students in their search for information relevant to their work* (α= .74, seven items). A five-point Likert scale ranged from 1 (*nothing supported*) to 5 (*fully supported*) was used.

An exploratory factorial analysis through the *Maximum Likelihood* method and rotation *Oblimin* confirmed the proposed structure of two factors (*KMO*= .82; X^2= 198.23, *p*< .001; 55.5% explained variance).

2.3 Procedures

Informed consent stating a voluntarily participation was signed. We administered the instruments with the help of teachers during session time. All instruments were anonymous and confidentiality of results was warranted. Data was analyzed using the multiple linear regression methodology (SPSS. 22).

3. Results

In order to determine how well the combination of independent variables such as the perceived importance of scientific competence in the curriculum, the mentoring, and the resources for research relates to the student's perception of acquisition of scientific skills partial correlation was conducted.

According to table 1, the correlations among the perceived importance of scientific competence in the curriculum, mentoring, and resources for research relate positively with the students' perception of acquisition scientific skills.

Table 1. Means, Standard Deviations, and Correlation scores of Acquisitions of Scientific Skills and Predictor Variables

Variables	*X*	*DS*	1	2	3
Development of scientific competence	3.35	.58	.51**	.29**	.34**
Predictor variables					
1. Importance	4.01	.55	-		
2. Resources	3.93	.98	.48**	-	
3. Mentoring	3.55	.84	.59**	.30**	-

*p< .05. **p< .01.

After reviewing the previous analysis, it was decided to include all the variables in the calculation of the multiple stepwise regression model was used to explore the relationship between predictor variables and the students' perceptions of their acquisition of scientific skills. We found thtat all the predictor variables are significantly related to the perception of students about their development of scientific competence (F= 183.69, p< .001). The model explains 41% of the variance of scores (see table 2).

Table 2. Summary of Regression Analysis for Variables that Predict the Development of Scientific Competence of Graduate Students

	B	*SE B*	*β*	*t*
Importance	.58	.03	.48	25.72**
Mentoring	.47	.17	.37	23.31**
Resources	.33	.19	.24	18.33**

Note: R^2=. 41; f^2= .69; F= 133.68; * p< .05. **p< .01.

4. Discussion

Results suggest that students' perception regarding to their acquisition of scientific skills is positively associated with the importance given to the development skills in the curriculum, to the available resources for developing research, and the quality of mentoring. These findings support the influence of policies that address these three elements in graduate programs to training scientists in graduate programs in Mexico (De la Orden et al., 2007; Moreno & Romero, 2011). Moreover, teachers in these programs must be encouraged to assist their students on an individual basis. In addition, to continue providing guidance, academic advice, and in some cases counseling for the students. Mentoring is a valuable element in the formation of the student when the same academic goals are established and developed in an environment of respect, trust and commitment between tutor and student (Torres, 2011).

We confirm how necessary is to understand the way a curriculum is implemented and what ~~are~~ its effects are on mentoring students (Coll, 1987; Hargreaves, 1986). However, our reported findings reinforced what other researchers have found. There is consistency regarding the importance that students give to obtaining research skills in their formation process as researchers contained in Sonora's graduate programs. Our results coincide with other studies where it is clear that graduate students' mentoring process is influenced by the way every student gains his/her own experience throughout the graduate program, also by the way the students manage the institutional conditions, that the programs have been implementing.

The interpretation of the outcomes mentioned above has a theoretical reference. Filloux (2004) argues through his formation concept that no one educate to anyone, that is to say, everyone educates himself. Thus, the doctoral programs can offer similar conditions to all the students, which involve them in the same activities and academic outcomes. However, the experience and narrative about it are unique and according to every single student.

Also, it is interesting to see the important role that play the mentoring and support for training students in their doctoral degree programs. Based on our results we reassert what has been reported in other studies, where graduate students consider that good tutors are those who provide guidance, strategic support and assistance to help them to gain control over their own learning (Byrne & Keefe, 2002; De la Cruz et al., 2010; Moreno, 2011; Paglis, Green, & Bauer, 2006).

All actions taken within the curriculum must emphasize the training purposes of the same so that the actors can define their goals and establish comprehensive, contextualized and comprehensive relations (Koetting & Combs, 2002). During this process the tutor promotes the development of work habits, attitudes and values to promote scientific and personal career of the student (Castro, 2006).

More studies that inquire into the graduate programs' usefulness since the students' perspective are needed to monitor advances and identify flaws. The results of this research contribute to the development of a field of study whose purpose are the thoughts, speeches, and actions of the teachers and students about the curriculum in which they participate.

Our study has restrictions as it is limited to a region in Mexico and is limited to quantitative data without explaining why students may have responded this way. Although exploratory level data that can be useful for managers and teachers of doctoral programs in the areas of science and engineering are given the results presented here should be interpreted with some caution, mainly due to the cross-sectional nature of the data does not establish causal relationships among variables.

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