

Introduction

The *linear model of accomplishment* is the path followed by professionals who wish to pursue an academic career. The model displays a number of sequential steps that each candidate ought to take if he wishes to pursue a successful academic career. In contrast, the *non-linear model* deals with professionals who, after the acquisition of their Bachelor's degree, for various reasons are not able to follow the *linear model* and are involved in a number of professional activities that, apparently, deviate them from a scientific vocation.

Linearity is a mathematical concept that has been used extensively in social studies. Many statistical methods of data processing in the social sciences are based on *linearity*, for example the multiple linear regression analysis. In social psychology, it has strong resonance in the context of the individuals' work environment, such as personal development. It is associated to areas related to career development, in efforts to reduce the impact of traditional, hierarchical systems of advancement characterized by a strict structural rigidity within the context of standard promotion systems. Past career models, according to Baruch (2004), "...had a clear, unidimensional or linear direction..." (p. 58). Upward mobility was in fact the measure of success and advancement, as the much-used analogy of the ladder suggests. In other domains of social studies, such as social hierarchies, *linearity* also refers to a certain pecking order in the line of command of some individuals over others. All of the above models are proposed as an attempt to express in mathematical terms diverse social phenomena. *Linearity* is defined as data that when graphed are shown as a straight line, not commonly seen in Nature.

The *non-linear model* has been practiced and gradually refined by the Centre for Innovation and Educational Development (CIDE). The Centre is a private non-profit organization created by academics working in public universities, in an effort to contribute

perspectives of the latter to visualize a furthering of the academic career. Wright and Wright (1987), on their part, make a case for the important role of the mentor in career advancement, and place special emphasis on its deficiencies in academia. The authors advocate nurturing students and young professionals into membership and leadership roles, and assert that this process should occur between junior and senior faculty as well as between graduate students and professors (Wright and Wright, 1987, p. 207). In a similar fashion, Fortes and Lomnitz (1994), in a study involving a group in a biomedical program, conclude that the nurturing process, where the professor/mentor plays a central role, became a key factor in the formation of undergraduate students into future researchers. The process the authors have outlined is, in our view, representative of the path in academia that we have defined as that of a *linear* academic development model. The following are essential features of that path, taken mostly from Fortes and Lomnitz' work on the training of researchers in Mexico (Fortes and Lomnitz, 1994):

- Requires full-time dedication
- A good part of the formation in the beginning relates more to a behaviour, to an *ethos*, the student must observe as an aspiring researcher, somewhat resembling, at the normative level, Merton's (1979) own view of the scientific *ethos*. Although Merton's views on the subject have been disputed, stressing the differences between actual practice and norms, this does not minimize the role of beliefs and values, as they pertain to science, in the formative stages of the young researcher's life.
- Also at the outset, a strict program emphasizing discipline and work-load, under the strict observance of a professor.

The model displays a number of sequential steps that each candidate ought to take if he wishes to pursue a successful academic career, namely: a bright student, after successfully finishing his Bachelor's degree in science, joins a graduate program; after becoming socialized in his new reference group, by accomplishing outstanding results in the laboratory or in the theoretical seminars, he starts to interact more intensively with one of his professors. If there is mutual understanding the professor "adopts" the student who becomes his assistant; the student in turn learns to behave accordingly in the world of academia, taking as a model figure his intellectual godfather (Fortes and Lomnitz, 1994). The student strives to reach the academic standards of his mentor and works hard to attain his level; he gets his PhD degree, perhaps gets a postdoctoral fellowship overseas; after one or two years of training abroad returns home to his original institution. With time he matures and becomes an important piece of the institution and, gradually, acquires independence from his mentor. If sufficiently brilliant, he may take his own way and initiate his own laboratory or department in the same institution or somewhere else. The cycle repeats when, in a professorial capacity, he takes on a graduate student. The model implies a steady financial support from the research institution and/or the public sector. Very rarely the student is supported by his family.

A non-linear model of academic career

In contrast, the *non-linear* model deals with professionals who, after the acquisition of their Bachelor's degree, for a number of reasons are not able to follow the *linear model* and are involved for instance in high school or college teaching, work in a laboratory as assistant, or in the case of women, marry and tend to child raising for some years. However, some of them, with an authentic scientific vocation, struggle for the

accomplishment of a higher degree and are willing to make any sacrifice to reach their goals.

A *non-linear* path displays key differences, being the most important the length of time it takes to arrive to *mainstream science*. However, both *linear* and *non-linear* individuals get to become full members of *mainstream science*, that is, they both reach the same end state. This illustrates the *open systems* principle of *equifinality*, as shown in Table 1.

Table 1. Comparison of stages to complete an academic career: Linear vs. non-linear model

Linear		Non-linear
Completes Bachelor's		Completes Bachelor's
Joins a graduate program	↔	Becomes a professional in his field (i.e. laboratory assistant, high-school or undergraduate lecturer), marries and raises family, etc.
Socialization in new reference group	↔	Search for alternative graduate education
Intense interaction with one professor	↔	Joins alternative education program
"Adopted" by professor. Becomes his assistant	↔	Socialization of knowledge sessions
Adopts scientist's ideology, behavioural transformation		Intensive use of ICTs
Obtains PhD		Learning/student-centred replaces lecture/teaching-centred. Flexibility in attendance and pace. Non-existence of course-work
Returns to original institution		Research-centred learning
Becomes independent researcher		Advised by a set of tutors, national and international
Research is recognized by the international community	↔	Establishes contact and collaborates with leading researchers in the field via Internet. Starts insertion into mainstream science
Joins mainstream science	↔	Obtains support for access to laboratories in institutional facilities for PhD research
Cycle repeats, he in turn "adopts" a graduate student	↔	Obtains PhD
		Research is recognized by the international community
		Joins mainstream science

↔ Indicates relative correspondence between stages in the two models.

Equifinality in *open systems* is the principle that a given end state can be reached by many different paths or trajectories. This is opposed to what happens in *closed systems* where a direct *cause-and-effect* relationship takes place between the initial condition and the final state of the system. The *linear model* behaves as taking place within the bounds of a *closed system*. What actually happens is that the career development described as a *linear model* is really a case where the individual is fostered by a number of actors of his immediate environment, as if he were protected within a bubble. Therefore he is not subject to external influences. In contrast, in the *non-linear model* the individual is subject to external forces that may distort his path, as is the case when he is acting in an *open system*. Table 1 illustrates the difference between *linear* and *non-linear* paths, as the latter exhibits some possible additional steps the individual must take to reach the same end-state.

As originally defined by Bertalanffy (1969), *equifinality* is said to be a general property of *open systems* such that "... vital phenomena show different behavior. Here, to a wide extent, the final state may be reached from different initial conditions and in different ways. Such behavior we call *equifinal*" (p. 76). Rapaport (1972) asserts:

Open systems, in contrast to *closed systems*, exhibit a principle of *equifinality*, that is, a tendency to achieve a final state independent of initial conditions. In other words, *open systems* tend to 'resist' perturbations that take them away from some steady state. They can exhibit homeostasis. (p. 53)

From the organization's point of view, many scholars have made contributions both to the concept and its application; Gresov and Drazin (1997), Katz and Kahn (1978), Van de Ven and Drazin (1985), and Donaldson (1985, 1995), among others. In the next section,

we will present an overview of the scientific career in Mexico as an introduction to the linear and non-linear cases.

Short overview of the current scientific career system in Mexico

Two major institutions constitute the support for the growth of science in Mexico: the National Council of Science and Technology (CONACYT) and the National System of Researchers (SNI). CONACYT was created in 1970 as the agency to support national S&T development (Velasco 1981, p. 404). Among other tasks, it provides fellowships for graduate studies both in Mexico and abroad. It also supports research projects proposed by groups of scientists. The SNI was created by presidential decree in December 1983 as salary compensation to contain the stampede and preserve the scientific community, as a consequence of the economic crisis of the time (Malo, 1988). It consists of a fellowship granted to the individual scientist according to his scientific merits. The SNI's objectives are to promote and strengthen, through peer-review evaluation, the quality of scientific and technological research and innovation produced in the country. The System contributes to the formation and consolidation of scientists with the highest level of scientific and technological knowledge as a fundamental basis to enhance the cultural base, and increase productivity, competitiveness, and social well-being (SNI, 2013).

Public expenditure in science has been of the order of 0.4 per cent of the GNP for more than 20 years, despite promises of the Federal government to gradually increase that figure up to 1 per cent. The number of scientists is 1 per 10,000 inhabitants, ten times less than in United States. The gross country-wise figure is of the order of 10,000 scientists (FCCT, 2010).

Currently the scientific career system in Mexico generally responds to the *linear model*. Most of the S&T is made in public institutions. There are a number of public

scientific universities around the country, with a major concentration of three in the Metropolitan area of Mexico City. The major producer of science and *linear* scientists is the National Autonomous University of Mexico (UNAM), which concentrates 47 research institutes in Sciences and Humanities (Agenda Universitaria, 2014). *Non-linear* scientists are observed more frequently in the provinces, where conditions for the realization of a scientific career are more reduced. Private universities do much less research than public ones, where Science is not a major priority for them; therefore their contribution to overall science in Mexico is very small.

Logical framework

In this section, we will present the cases of four students, two *linear* and two *non-linear*, which will serve as examples of the two different types of academic development. The *linear* examples were collected from the Scientific Research Subsystem of the National Autonomous University of Mexico (UNAM), by far the largest university in Mexico, and possibly Latin America, and where most of the basic and much of the applied research is realized. As it is a public university, most of the funding comes from the Federal government. The non-linear examples were taken from a non-conventional, alternative education learning and research institution, the CIDE (described briefly below), which caters to just those individuals who are not able to follow a traditional educational trajectory.

The Centre for Innovation and Educational Development (CIDE) is a non-conventional, virtual institution that has become an attractive educational alternative for students who are not as comfortable following conventional education or whose age and occupation does not allow them to engage in a formal graduate program, as was previously stated (Jiménez, 2007).

The model combines learning based on problems, self-study, flexible curriculum, intensive use of ICT's, acquisition of generic competencies for research. It is a virtual, learning/research community of university professors, from different public institutions. It has no physical infrastructure. Professor/advisors do not receive a salary. Students and advisors meet once a month for two full days to socialize knowledge and advance the students' projects. Students usually already teach full time in educational institutions (Jiménez, 2007).

Although the Centre attempted to represent an alternative path within the bounds of formal higher education in established state universities, for a number of years it exhibited mixed success. Intermittently, it enjoyed acceptance and full certification at some institution, only to be ousted at the next change of authorities, in part due to the innovative outlook it brings to higher education. It was not until the Centre formed an alliance with another singular alternative education project, CEJUS (Justo Sierra Study Centre)¹, that it gained full recognition and certification. CIDE now has branches in different parts of Mexico, working with relative independence from each other and from the central node located in CEJUS. Both projects, like Weick's (1976) loosely-coupled organizations, are unique in that there are no hierarchical relations or clear command linkages between any of the members, staff, students or professor/advisors.

¹ CEJUS, as we described in a previous work (Jiménez, 2007), is another experience in innovative education that merits separate mention. The Centre, in which one of the authors has participated for more than three decades, was started as a consequence of the demand by the local Parents' Association to improve the quality of elementary education for their children. Subsequently, their demand broadened its scope to pre-school and agricultural post-elementary education, to prevent their children from having to abandon the community to study in Culiacán, the state of Sinaloa's capital city, and thus begin a process of alienation from the community. Today, the –Centre boasts the "Universidad de la Sierra" (The University of the Mountain Range), offering bachelor's programs in sustainable use of natural resources, under a joint administration with CIDE, where the latter's central node is housed (see also Jiménez (1992) and the Centre's own publication, *Community Self-development* (Comité de Planeación Educativa, 1980), for additional information.

The data for the study were collected from primary and secondary sources. Primary sources consisted of surveys in the form of questionnaires and interviews. Secondary sources were the analysis of the individual *résumés*. The names of the scientists selected were changed to preserve identity.

Within the case study methodology we apply an interpretive approach as it employs an inductive path that starts with data and derives in an explanation about our phenomenon of interest. Being interpretive, our study does not need either to test a hypothesis, or a representative sample. Our aim is to reach a documented explanation of how the *non-linear* phenomenon takes place. One of the authors has been involved for 33 years in the CEJUS project as external advisor, and has intervened in the shaping of the institution as it is now. The two authors have interacted with the CIDE project since 2005 as field observers.

Two examples of *linear* models in science

The case of Lupita.

Lupita got a Bachelor's degree in Science in 1982, at the age of 22, from a Mexican prestigious university. She then went on to a Master's program at the same University, where she graduated in 1984, just two years later. She continued her graduate studies in a foreign prestigious institution, and completed her PhD five years later, in 1989, at the age of 29.

Upon completing her Bachelor's degree, in 1982, while doing her Master's, she began to work in an institute. After she completed her degree, she was promoted to Associate Researcher "B"² in 1985. In 1989, as she completed her PhD studies, she was

² In Mexican universities there are two academic categories Associate and Full Researcher, and three levels in each category: A, B, and C.

promoted again to Associate Researcher “C”. In 1995, she was promoted to Full Researcher “A” and tenure was also granted. In 2001 she obtained the category of Full Researcher “B”, at the age of 41.

She belongs to a number of collegiate bodies and professional associations and has been head of her Department. She has received a number of distinctions including her acceptance in the SNI. She has authored and co-authored a great number of articles, as well as chapters in books and technical reports, and has been speaker in diverse international academic fora. Currently, she teaches in a Graduate Program and tutors a selected number of students.

The case of Ignacio.

Ignacio has had an even more vertiginous career. In 1994, at the age of 23, he graduated as a Bachelor in Science. In 1995, Ignacio began working at a research institute of the same university where he did his bachelor’s degree. That same year, he left the Institute and joined a PhD Program in a foreign prestigious university, completing his degree in 1999. Upon his return, he was named Associate Researcher “C” in 2000. In 2007, he was promoted to Full Researcher “A” and tenure was granted. In 2010, Ignacio was again promoted to Full Researcher “B”. He has received a number of distinctions including membership in the SNI. Ignacio has published more than 34 articles in internationally recognized journals, as well as two books and seven chapters in books. He has been a speaker in many international fora, has taught in several institutions, and has tutored a number of students in different university levels. In 2012, he was appointed the Institute’s Director, at the age of 41.

Two Examples of *Non-Linear* Models in Science

The case of Juanita

In 1977 at the age of 27, Juanita got her Bachelor's degree in Microbiology at the Autonomous University of Coahuila (UAC), Torreón, Mexico. After finishing college, Juanita started working as a Technical Assistant in the Mexican Institute of Social Security (IMSS), a national health institution. In 1981, she was promoted to Full Technician in the Microbiology Laboratory. Her boss motivated her to continue learning and getting professional certifications. She attended special courses in the IMSS headquarters, and delivered her new knowledge with her co-workers. Her work unit, under her guidance, created a national certification program that was taught for eleven years.

Juanita's passion for Microbiology is focused on fungi research. In the geographic region she is working, cases of coccidioidomycosis, which is a lung mycotic disease, were detected with relative frequency; however they were usually misdiagnosed as pneumonia. In her experience, patients went from one level of specialization to another with different treatments. After months of misdiagnosis, patients were turned to her unit. Sometimes, when the disorder was detected, it was too late to do something to save their lives. She felt the need to know more about this situation, and started doing research herself. She got invited to a symposium on coccidioidomycosis in California, USA in 1987. In 2004, there was a call for grants about rare organisms in the environment. Juanita applied for a grant, and her proposal was funded for three years by CONACYT. In September 2006 at the age of 46, she got invited to join an alternative doctoral program at CIDE in Surutato, Sinaloa. In November, 2008, at the age of 48, she got her doctoral degree specializing in Coccidioidomycosis.

As result of her research, Juanita found out the geographical area she was studying was an endemic zone in Coccidioidomycosis in Northwest Mexico. She helped to develop correct diagnosis procedures for this illness, thus giving patients the proper medical treatment, and saving many lives. From then on, patients could get access to vaccines, medication, and preventive measures. She currently belongs to the network of top specialists in this mycotic specialization, at the age of 52.

The case of Ambrosio

Ambrosio is another good example of a person who achieved academic success by a path other than the established one. He studied Civil Engineering at the Autonomous University of Sinaloa (UAS), Northwest Mexico, from 1980 to 1985. Before he finished his university studies, he taught Mathematics at the Guasave High School, Sinaloa, during the period from 1984 to 2002. He finally got his Bachelor's degree in 1994, at the age of 32. From 1999 to 2000, he taught Mathematics at university level at the "Universidad de Occidente", Guasave. Ambrosio got a Master's degree in Regional Development Planning (UAS), in 2000. He then got a position as Full Time Teacher in Mathematics at the Guasave High School, from 2002 to 2009.

In 1998, Ambrosio learned by searching current scientific literature, that gold absorption may be induced in plants. This process known as induced hyper-accumulation of metals in plants, has drawn the attention of both scientists and entrepreneurs. Mexico, with a long mining tradition did not have a team of scientists to research in "phyto-mining". Ambrosio contacted the only two existing specialists in the world, one in New Zealand, the other in Switzerland. He established an academic relationship with one of them, Dr. Anderson of New Zealand. At the same time, he started his PhD studies. His doctoral work was realized with the external tutorship of Dr. Anderson who proposed Ambrosio to

experiment with eight species of plants, in an area where mining waste was deposited, three of which yielded a profitable gold “crop”. Ambrosio got his PhD in 2008, at the age of 46. In 2009, he reached the position of Full Professor “C” in the area of Mines and Metallurgy in his University.

As a result of his PhD research, Ambrosio became one of the few phyto-mining specialists in the world. He has continued research in phyto-extraction of gold settled in mine waste, since 2002. From that year on, he has built his own scientific network with both national and international academics in the field. Ambrosio has headed five financed research projects, since 2006. Since then, he has presented papers overseas and published in international journals. This shows Ambrosio is very active in his area of research, and is making his way to *mainstream science*.

Conclusions

We have shown there are two well-differentiated paths of career development in academia: the *linear* and the *non-linear*. By virtue of the *equifinality open systems* concept, it may be shown that both reach the same end state, namely the incorporation of the individual into *mainstream science*. The *linear* path is somehow straightforward, whereas the *non-linear* is not. A major difference between the two is that the *non-linears* take more time to reach the end state. Not many institutions allow following a *non-linear* track. Moreover, formal institutions are reluctant to help/encourage individuals to take such track. However, in Mexico there is a non-conventional institution which does: the Centre for Innovation and Educational Development (CIDE).

Globalization does not necessarily mean a widening of the gap between the industrialized countries and the countries in the process of advancement. There are opportunities for less developed countries to take advantage of the world explosion of ICTs

and the networking possibilities it implies, at a relatively low cost. The *non-linear* examples described here are precisely forms of using modern technologies to the benefit of communities apparently left behind from the general progress.

It is interesting, and to a certain extent paradoxical, to notice that the professors who sustain the CIDE model are not themselves inserted into *mainstream science*. However, they have the ability to help students approach higher and visible levels of international academic recognition. The “secret” is that they both intelligently and generously designed and implemented an academic model to take advantage of some features of globalization to help non-conventional students to get a PhD degree in sciences, putting in practice an innovative way of learning and research aimed to prepare new scientists and, concurrently, solve specific research problems detected by the students in their own geographic region. The professors dedicate one weekend per month to attend students, and during the week days, they review the students’ academic products to offer feedback to them during the socialization of knowledge sessions.

In the process of research, students interact with scientists, via Internet, at the frontier of knowledge thus creating their own network that also includes national scientists. This type of new networking is highlighted by Wagner (2008) as a product of the globalization of the ICTs, that connects scientists not only North-South but also South-South, bringing benefits to more segments of the world population.

In synthesis, CIDE’s experience demonstrates that it is possible to reach desired objectives by making operational the design of a system whose parts enjoy ample flexibility, without the need for a costly physical and human infrastructure. The “glue” that brings together the different parts of this system is, convincingly, the motivation that each member has for reaching his particular objectives as well as CIDE’s general objectives.

Further research into the relationship of the *non-linearity* concept and *equifinality* is clearly necessary. It opens a new path to fully understand how academic careers develop in the wider social context of structural change taking place in the turbulent environment of globalization.

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