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SYSTEMIC FACTORS OF THE AEROSPACE ENGINEER LEARNING CURVE

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Abstract: This work studied the progress made by the communications and electronics engineers (CEES) working at Servicios a la Navegación en el Espacio Aéreo Mexicano (SENEAM), with the aim of establishing their transitions and projections while working at this company, and acknowledging the learning curve by this staff from their beginnings as CEES in the corresponding area of IDS, communications, radio aids or radar operations. Learning curves are empirical models that allow studying technological transformations as a result of learning processes. From this, learning is understood as the knowledge we acquire from the repetition of a process (learning-by-doing) (Arrow, 1962). Wright (1936) published an article stating that the learning curve phenomenon was observed for the first time in 1920. On this regard, Hirschmann (1964) comments on the benefits of the learning curve that "practice makes perfect, and things can be done better not only the second time, but every time we try." Hence, the learning curve is the one in charge of quantifying and graphically representing this performance (Hirschmann,1964). In this context, SENEAM, which has more than 40 years of experience in the Mexican aeronautical industry, provides air navigation assistance services with safety, fluidity and order, ensuring quality and efficiency in accordance with applicable national and international regulations. Consequently, this research is expected to reveal the factors that determine the learning curve of CEES in the airline industry through the case study of SENEAM.

Keywords: Learning curve; Training; Mentoring, QHS Methodology

INTRODUCTION

The learning curve is the result of experience, of man's contact with his environment (Chango, 2014). The importance of this work is to know all the functions of a communications and electronics engineer (ICE) who works in Navigation Services in Mexican Airspace (SENEAM). SENEAM is a decentralized agency of the Ministry of Communications and Transportation (SCT) of Mexico, which was created by presidential decree and published in the Official Gazette of the Federation (DOF) of October 3, 1978 (DOF, 1978). This organization's mission is to guarantee, through navigation services, the safe and efficient transport of people and goods in Mexican airspace. To establish the learning curve, it is necessary to provide information on the projection for the development of sectoral competencies through the generation of a profile of the ECIs that work in the aeronautical sector in Mexico.

The importance of adequate training for the communications services, radio aids and radar engineering personnel of an organization such as SENEAM is paramount because air navigation services must be guaranteed with the highest standards and efficiency, as set out by the International Civil Aviation Organization (ICAO) in Annex 10 and the current regulations of the Federal Civil Aviation Agency in Mexico.

In the paradigm to provide feedback on the knowledge and skills necessary in the different equipment and systems that are handled in the aeronautical sector, SENEAM complies with the ISO 9001-2015 standards, section 6.2 of human resources that establishes the quality management system. With the implementation, this study seeks, through the learning curve, that an ICE acquires in a shorter time the competencies required to get a position in the aeronautical sector, in addition to being a necessary resource for administrators who need to know how the development of the training of ICEs who enter to work in the air sector over time was. By generating engineering personnel with homogeneous, continuous and updated training in technological advances, the optimal performance of radio navigation equipment and aeronautical systems used in the air sector is provided.

Emergence of the learning curve

In February 1936, Patterson Wright published in the Journal of the Aeronautical Sciences, volume 3, the article entitled "Factors Affecting the Cost of Airplanes", the first recorded publication on the learning curve, which arose from his first studies carried out in 1922 on the variation of costs in the aeronautical sector. In this learning curve, Wright represented the variation of the empirical work, and from two or three points of experience in producing the same model in different possible. Over the years, this curve, which at first showed only the variation of the work, was used for the estimation of purposes and more data were corrected until it became available and was presented on paper (Wright, 1936). In his 1936 paper, Wright states that the learning curve phenomenon was first observed in 1920 in Dayton, Ohio, United States, in the American Air Force. There it was found that 80% of the hours of the first type were spent in the assembly of a second aircraft of a certain type. The eighth plane spent 80% of the hours of the fourth, and so on until a logical limit was reached (Chango, 2014).

Learning Curve Hypothesis

Wright's hypothesis was that the man-hours needed to complete a unit of production would decrease by a constant percentage each time production doubled (Chango, 2014). In industry, the learning curve is used in the time and cost of production. Figure 1 shows the accumulation of what has been learned on the X-axis, and the time spent on the Y-axis. The emergence of the learning curve in the aeronautical sector has been known since Wright in 1920. However, Terrazas et al. (2009) have indicated that the idea of individual learning and organizational learning began in the seventies and was applied by the Boston Consult Group and de Conley.

In Figure 2, the learning curve shows the work. The overall shape, the trend of the data, and the correction of the curve were due to the new points; These in turn corresponded to the results of the data of the experience acquired, which have made it possible to draw another curve that shows the rate of change of the material used, the material purchased and the aircraft as a whole against the quantity. On the other hand, Arrow (1962) first proposed the hypothesis about the economic implications of learning. This model, one of the most required, proposes a learning rate that is described as a percentage, in which costs are reduced once production capacity is doubled. Learning curves are empirical models that facilitate the study of technological evolution as a result of knowledge (Arrow, 1962). In this area, learning is understood as the experience that is acquired by the repetition of a process (learning-by-doing); For example, increases in production capacity leave an experience due to repetition in a production process.

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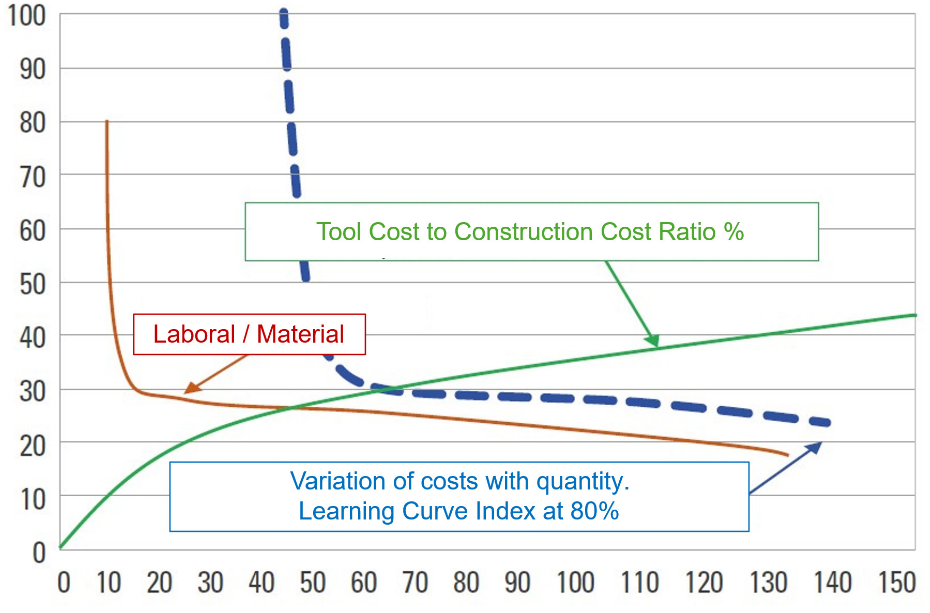

Figure 1. 1936 Learning Curve, Source: Wright (1936).

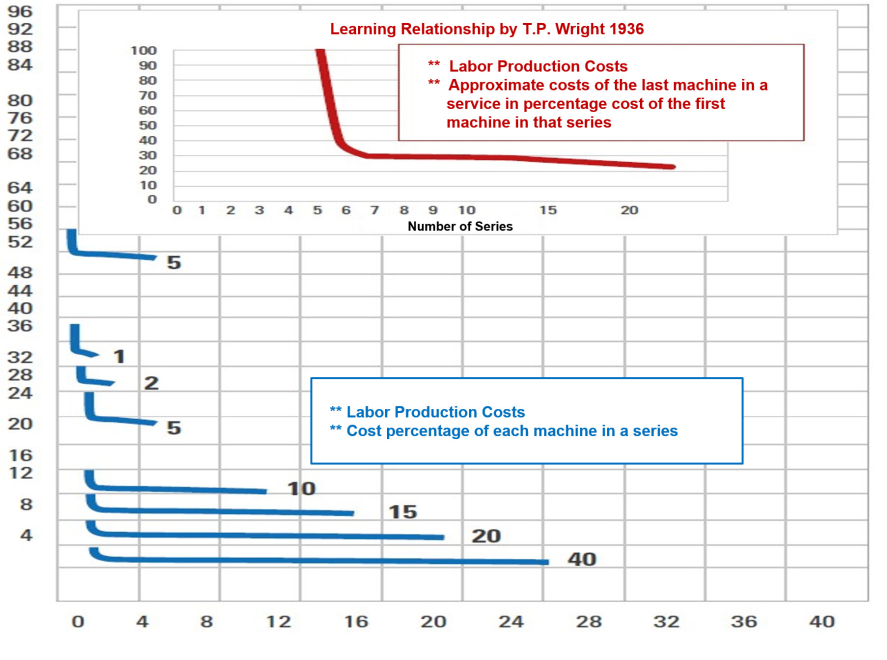

Figure 2. Learning Curve with the General Form and Trend (Wright, 1936).

"Practice makes perfect," said Hirschmann (1964). You can always do one thing better, not just the second time, but every time you try. Everyone knows this, but how many know that a pattern of improvement can be regular enough to be predictive? How many realize that such patterns can characterize not only individual performance, but also the composite performance of many individuals organized to perform a common task?

Learning curve performance is a natural feature, so learning curve performance should be localized not only for more types of activities already registered as responsive, but also for unlikely functions, such as those that were not previously announced or believed to be susceptible (Hirschmann, 1964). In Figure 3, the points show a decreasing trend for productive working hours in maintenance and shutdowns between the years 1949 and 1956. At the end of that period the plot seems to l evel out.

If management had speculated on this curve, it might have felt that it had reached a stable level and that maintenance had learned the best way to do the work required so that a new decline would not occur – at least for a while. But, in reality, the trend continued, ending where it should have been expected (Hirschmann, 1964). In this sense, the work is greater for positions that demand a high degree of manual activity and in which, in addition, traditional methods are being applied. In certain cases it is necessary to show the worker films or videos in which traditional procedures and new movements that will be applied in the most effective way are presented, as well as the fact that a habit is an activity that influences the increase in productivity by reducing the need for conscious reflection (Kanawaty, 1955). In the theory of continuous improvement in a learning curve, a continuous effort is made to improve the worker's performance and make him more productive (Willard & Kantor, 1998).

When carrying out an analysis of learning and its definition, these three aspects are detected:

1. It is a change in behavior or in how the individual performs his or her work because he or she has assimilated an activity and already does it differently from the previous times.
2. It includes the development of a capacity to manage oneself. This means that the person, as he or she gets to know the tasks, acquires skills, develops skills and acquires sectoral competencies that will remain in time.
3. It is a result of practice where he acquires skills, abilities and knowledge that lead him to accumulate experience, for example, by trial or error, or by observing others through example; something similar happens when human beings learn to speak.

How the learning curve works

In the concept of learning and with the intention of knowing the functioning of learning curves, which shows the factors that influence learning. These can positively or negatively alter their performance, among these factors are, for example, the speed of learning, which is measured in a ratio of 80% and is called the learning rate. A lot of these improvements come from searches people do to improve performance: they're

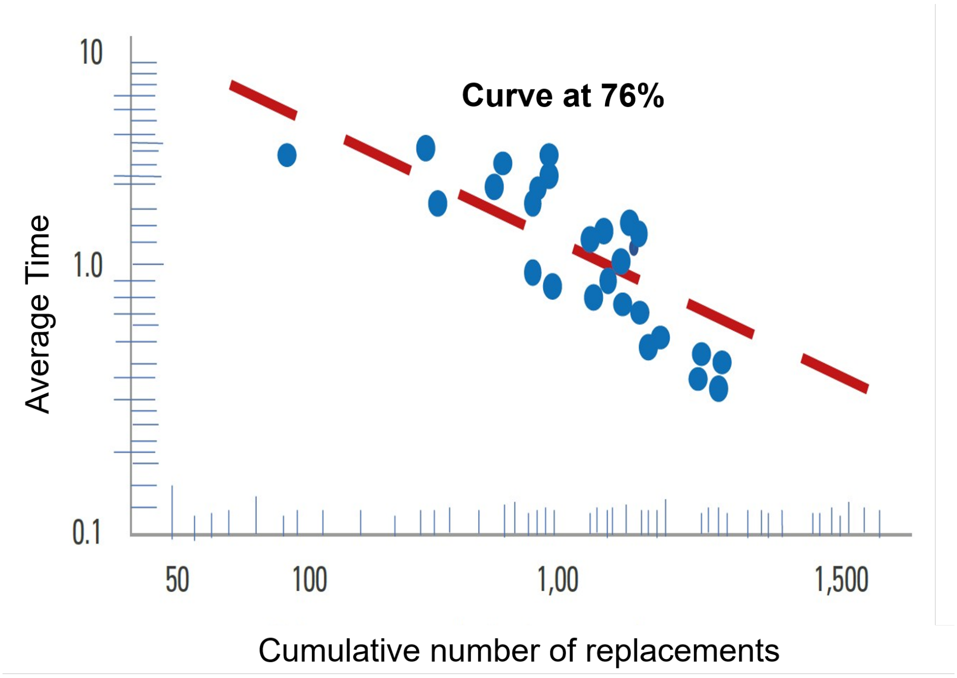

Figure 3. General Electric Plant Maintenance Learning Curve (Bennet, 1957).

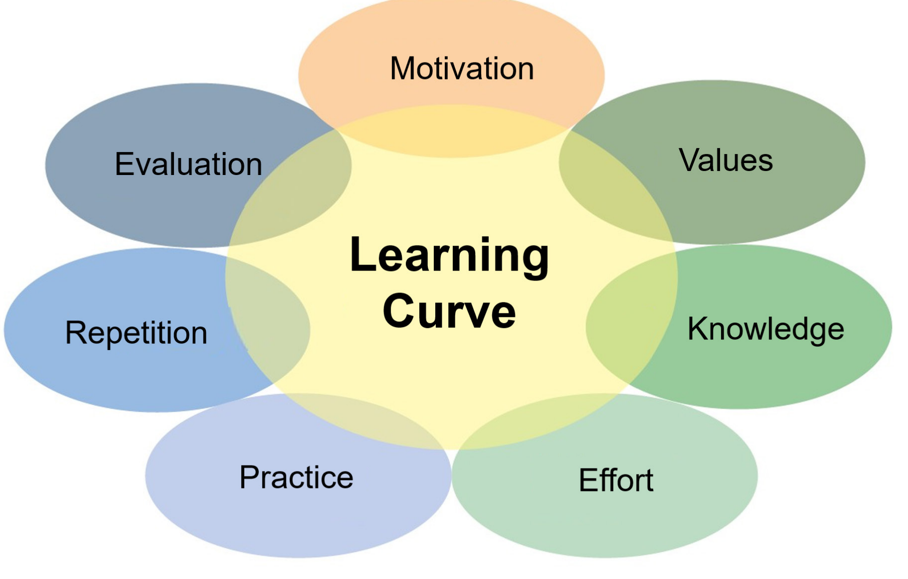

Figure 4. Elements that influence learning (Chango, 2014).

known as online improvements. Others, on the other hand, come from different sources, including new tools, new materials or offline reengineering or improvements. Figure 4 shows the elements that must mark learning as a process (Chango, 2014).

Learning is understood as a process, and it has elements that demonstrate it: in any learning process there is a reason for need and an intrinsic or extrinsic interest in the activity; it is made up of common values, information and data; it is motivated by challenge, which shows a level of effort for what is expected by the worker (Chango, 2014). Discipline is a constant practice and repetition that leaves an experience in the tasks, in which knowledge is accumulated to reevaluate learning and promote collaboration between peers that is relevant when receiving feedback from an organization or from those involved.

Logarithmic Learning Curve Method

Various authors such as Krajenski (2000) and Terrazas et al. (2009) indicate that the logarithmic method will facilitate the determination of the learning curve for any unit, TN, by the following formula:

Logarithmic method TN = T0 × Nb

Where:

x = Number of units.

Yx = Number of direct man-hours required to produce the nth x.

K = Number of direct man-hours required to produce the first unit.

N = log goes log2, where b = percentage of learning.

Learning Percentage Estimate

Organizations and products have different learning curves. The rate of learning will change according to the quality of management and the potential of a process and the product. In this order of ideas, the learning rate in the airspace sector is 85% (Chango, 2014). In the studies carried out by Wright and published in 1936 where he mentioned that in a fourth plane he spent 80% of the hours of the second. The eighth plane spent 80% of the hours of the fourth and so on until a logical limit was reached. The speed of learning is measured with this relationship, (80%) and is called the learning rate. The lower the learning rate, the longer the learning curve (this is the only time when 60% is better than 80%) (Ballesteros et al., 2005, p. 185).

Methodology

A qualitative research was carried out with a type of non-probabilistic convenience sampling, in which the reasoning of a sample is used to make it more profitable for the research topic. It is a type of intentional sample where there is a key informant who identifies another to interview. For the purposes of a comprehensive research, the systemic approach and analysis of the sectoral environment must be considered (Martínez, 2012, 2020). Thus, 50 engineers were chosen on the condition that they work in service engineering in radio aids, communications and radar in the various stations of the Mexican Republic. Of the total, 47 were men and 3 women. As for the years of service they had been working in the agency, the range ranged from 5 to 47 years.

Instrument Design

To elaborate the design of the information collection of the research instrument, a presentation of the variables was made in a reliable way,

valid and objective. According to the writers, any instrument used must meet at least two conditions: reliability and validity (Rojas, 2011). Thus, the following instruments were used to collect the information:

a) Direct observation.

b) Questionnaires.

c) Interviews.

For the survey, the Likert scale 5 was used with the values:

5=excellent, 4=very good, 3=good, 2=fair, 1=bad.

For the validation of the instruments (surveys and interviews), the judgment of experts was used (Skjong & Wentworth, 2000). As the judgment of experts, a knowledgeable opinion of individuals with experience in the subject is known, who are recognized by others as authorized experts on a certain matter, and that they manage to provide inquiry, certainty, reflections and appreciations. The number of judges to be manipulated in a trial depends on the level of expertise and the complexity of the discernment; The decision on how many experts is appropriate varies among different authors. Thus, while Hyrkäs et al. (2003) suggest a range of 2 to 20 experts, stating that 10 would provide a reliable assessment of the content validity of an instrument. If 80% of the experts have agreed with the validity of an item, it can be incorporated into the instrument. In this research, the instrument was shared with 15 experts in the topics of training and high development in the SENEAM agency, who were asked to evaluate the research instrument, considering their appreciations and contributions to improve the instrument. Table 1 presents a breakdown of the factors measured in the questionnaire, as well as the items of each factor and the percentage that corresponds to each one according to the total of those used for the implementation of this tool, which indicates the variable to be studied that provides information for the conclusions derived from the research.

Procedure

Regarding data collection, Sampieri (2010) states that it is an elementary process, although the objective is not only to determine a variable to establish conclusions and statistical studies; What is sought in qualitative research is to obtain data (which is transformed into information) on individuals, populations, problems or in-depth issues. Data collection was carried out in the respondents' natural and everyday environments or units of analysis. In the case of people, in their daily environment: how they speak, what they believe, what they feel, how they think, how they act. Available technological tools were used in data collection, since the respondents were in various locations of the national territory in Mexico.

In the data collection, the following steps were followed:

1. Data search: in this stage, information was collected that provided knowledge, while in parallel the data collection was carried out (where a researcher was an instrument). In the same way, the data

Factors	Questions	Total items	%	Variable to study
Basic Info	1 – 5	5	3.42	Independent
Career Development	6 – 8	3	2.05	Independent
Meritocracy	9 – 11	3	2.05	Independent
SINCO	12	16	10.96	Independent
Job Functions	13 – 15	23	15.75	Independent
Mentoring	16 – 18	3	2.05	Independent
Competencies	19 – 28	10	6.85	Independent
Training	29 – 42	58	39.73	Dependent
Learning Curve	43 – 62	20	13.7	Dependent
Job satisfaction	63 – 64	2	1.3	Dependent
Work motivation	65 – 66	2	1.3	Dependent
Work teams	67	1	0.68	Dependent
Totales		146	100%	Dependent

Table 1: Breakdown of the factors that were measured in the sample

were analyzed, transcribing the information that was collected through a process log in which the results were recorded.

2. Data collection: the instrument for collecting the information was the interviewer himself, who, through the tools applied, collected the data.

3. The following tools were used:

a) Survey.

b) Interviews.

c) Observation.

4. Data analysis: it began with the formation of all the data that was collected and used.

a) The organization of information.

b) Registration of the material.

c) Computer programs were used to organize the information.

5. Material analysis: the main (and essential) methods were rigor, validity and reliability.

a) Dependency.

b) Credibility.

c) Transfer.

d) Confirmation.

6. Information coding: the coding of all the information that was received was carried out through two levels:

a) First level: equalization of the elements to generate some classes.

b) Second level: equalization of the following categories:

1. Data analysis.

2. Pattern making.

3. Origin of assumptions, explanations and theories.

The stages (activities carried out to reach the proposed goals of the research and obtain an answer to the questions of the

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study), were put together because they were repetitive and persistent; that is, there were no times in development where it could be mentioned "here one stage ends and another follows". By observing in each one and witnessing what was happening, information was analyzed and collected, and the analysis ended in parallel activities. That is, the analysis was developed at the same time as the information was obtained, in such a way that the initial sample was not conclusive if the analysis evolved by continuing to collect the information.

Application of the instrument to service engineering personnel (IDS)

Rojas (2011) states that validity is a quality of the instrument if it serves to measure the variable to be measured and not another; that is, that it is the instrument precise and adequate. An adequate measurement instrument is one that records observable data that truly represent the concepts or variables that the researcher has in mind (Sampieri, 2010).

In this research, the researcher designed a questionnaire with questions aimed at collecting information for each of the variables, as well as the way in which they are administered for the recording of the observations that are the property of the study researcher himself, collecting information dependent on interviews with successful personnel in their permanence in the agency of different managements of the country in order to obtain a more accurate sample. The information obtained from the application of the instrument was analyzed and classified to make a projection of the ICE in their working life in the SENEAM agency. This projection is determined by several factors that provide information used to make the learning curve of the ICE of the air sector in SENEAM.

Figure 5 shows the years of work of the engineering personnel who participated in the research. The year of entry into the agency and, with that, the years of service for the projection in his career within the agency was known. It was obtained, firstly, that 26% of the respondents (13 people) have been working in the agency for "6 to 10 years"; secondly, that 20% (10 people) have been working "from 31 to 35 years", and, thirdly, that 18% (9 people) have worked "from 11 to 15 years".

In Figure 6, the area where engineers work who participated in the study sample, it was obtained that 82% of the sample, equivalent to 41 engineers, they work in IDS communications and radio aids; that the 8% (4 respondents) do so on IDS Radar; 4 other people work in Radar Processing, and 2% (1 respondent) works at DISDA.

Figure 7 shows the time elapsed for the ICE to obtain its first aeronautical license as a class II aeronautical technician, issued by the AFAC, which enables it to intervene radio aid equipment or radar systems. 84% waited 1 to 5 years to obtain their first aeronautical license; 6% from 6 to 10 years old, and another 6% who said they did not have a license.

Figure 8 shows the level at which the respondent entered the agency. First, with 88%, 44 respondents entered with level 69; in second and third place, 4% (2 engineers) with level 71 and level 73, respectively, and, finally, 2% (1 respondent) with level 63.

Figure 9 seeks to know the factors that influence the rise in the level of ECIs. In this

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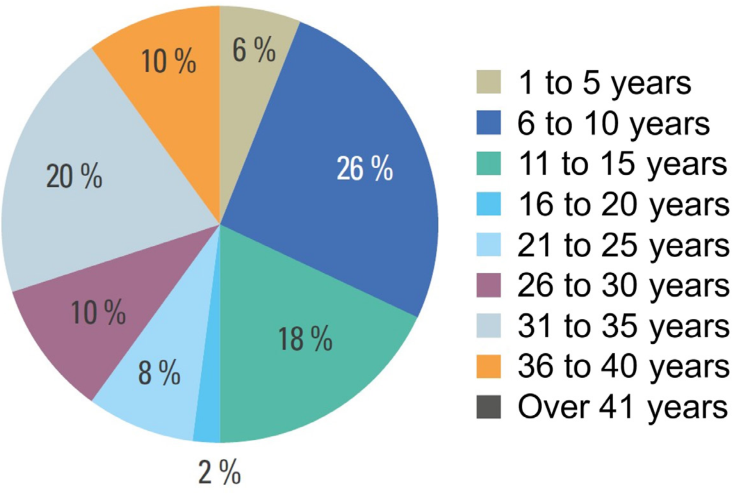

Figure 5: Years working in the institution

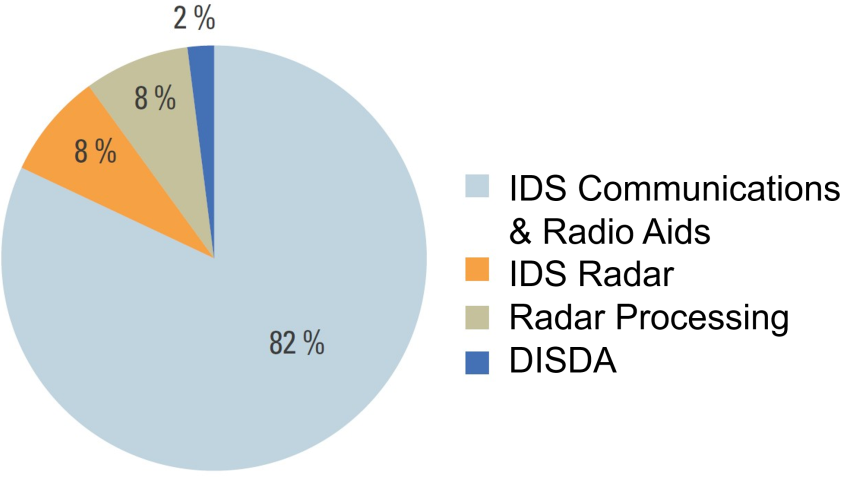

Figure 6: Specialization of Engineers in Research

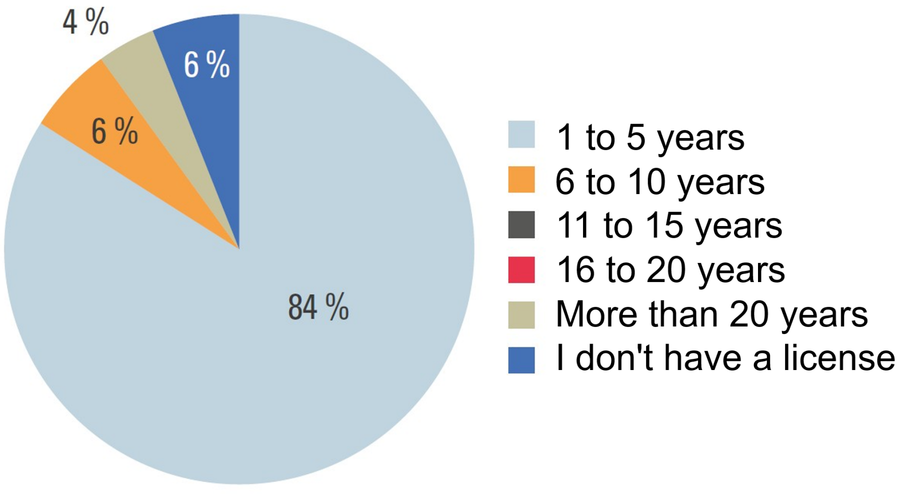

Figure 7: Average time to license

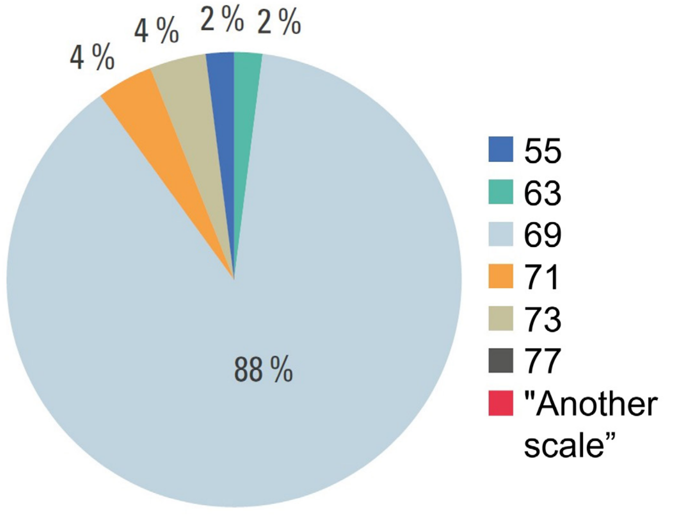

Figure 8: Level of the interviewee in the research

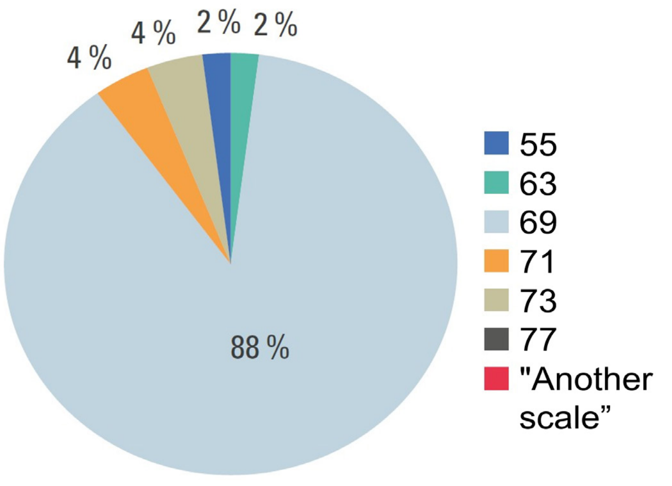

Figure 8: Respondent Level

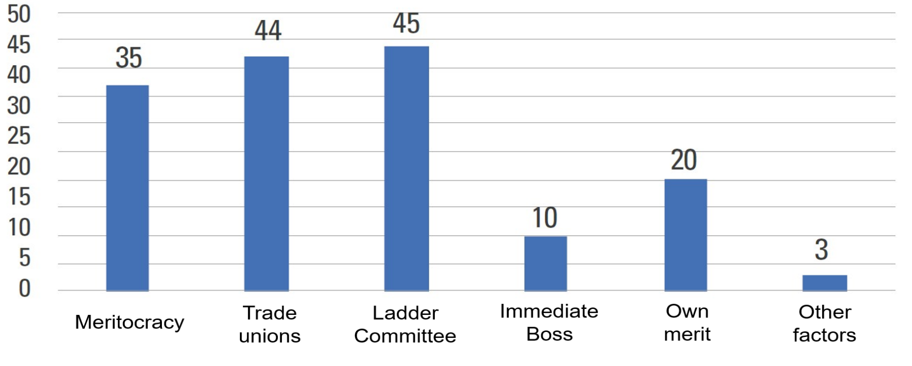

Figure 9: Factors influencing the level rise of ECIs

regard, 45 engineers considered the ranking committee; 44 engineers pointed to the unions; 35 engineers indicated meritocracy; 20 engineers considered their own merits; 10 engineers chose the immediate boss, and 3 engineers answered "other factors."

Figure 9 seeks to know the factors that influence the rise in the level of ECIs. In this regard, 45 engineers considered the ranking committee; 44 engineers pointed to the unions; 35 engineers indicated meritocracy; 20 engineers considered their own merits; 10 engineers chose the immediate boss, and 3 engineers answered "other factors."

The SINCO (National System of Classification of Occupations) is made up of a technical committee of a series of private and government institutions from all the productive sectors of Mexico, who provide information from experts and surveys that, through the National Institute of Statistics, Geography and Informatics, are carried out throughout the country (INEGI, 2011). The SINCO, in unit group 2281, mentions the 16 job functions of electronics engineers and telecommunications. These functions are presented in Table 2, where it is evident that 75% of the respondents usually perform these functions.

Figure 10 shows the careers of the respondents. All careers have differences in terms of the profiles required by the curricula designed by the universities, that is, when engineers are hired, there will be cognitive technical needs that must be covered with training that provides feedback to the requirements that the aeronautical communications service industry requires today. First, 62% (31 respondents) studied Communications and Electronics Engineering (ICE); secondly, 18% (9 respondents) are electronics engineers; in third place, with 8%, 4 respondents are telecommunications engineers; 4% (2 respondents) studied Medical Engineering; the other respondents, with 2% each (equivalent to 1 respondent per career), studied Computer Systems Engineering, Mechatronics Engineering, Industrial Electronics Engineering and electronic technician.

Figure 11 provides information on sectoral competencies; It seeks to make known how engineers consider their training and where it is oriented to develop the sectoral competencies of engineering personnel. It was found that 90% (45 engineers) answered yes, and 10% (with only 5 engineers).

Figure 12 shows the meritocratic level of the engineer, which provides us with information on his projection within the organization, as well as on the sectoral competencies. In first place, equal with 28% (14 respondents), are levels 73 and 79; in second place, with 14% (7 engineers) level 77; in third place, with 12% (6 respondents) level 80.

Figure 13 provides information on sectoral competencies, from which it is known whether the engineer has an aeronautical license issued by the AFAC. 82.1%, only 32 of the respondents, answered yes; while 17.9% (7 respondents) answered that they do not have the type II aeronautical technician license that enables them to use radio aids or radar systems.

Training, according to Dessler and Varela (2011), refers to the methods used to give workers new skills that they require to perform their work efficiently and with quality. Figure 14 shows what is perceived in the initial training when receiving the course of the basic subjects, which will contribute to improving the cognitive and sectoral know-

Job Functions	Quantity	Percentage
Detect and correct equipment failures	48	96%
Monitor equipment operation	48	96%
Equipment and system installations	47	94%
Equipment and system installations	46	92%
Prepare technical diagrams per installation	40	80%
To dictate and/or apply technical standards	37	74%
Monitor facility activities	37	74%
Produce diagrams for Tx and Rx data	36	72%
Coordinate work with external suppliers	31	62%
Define procedures for installations	30	60%
Formulate and approve quotes	26	52%
Write reports on designs and projects	25	50%
Design projects for development	18	36%
Standards for control and good service	12	24%
Lead systems development activities	12	24%
Research to implement systems	11	22%

Table 2: Job functions according to SINCO

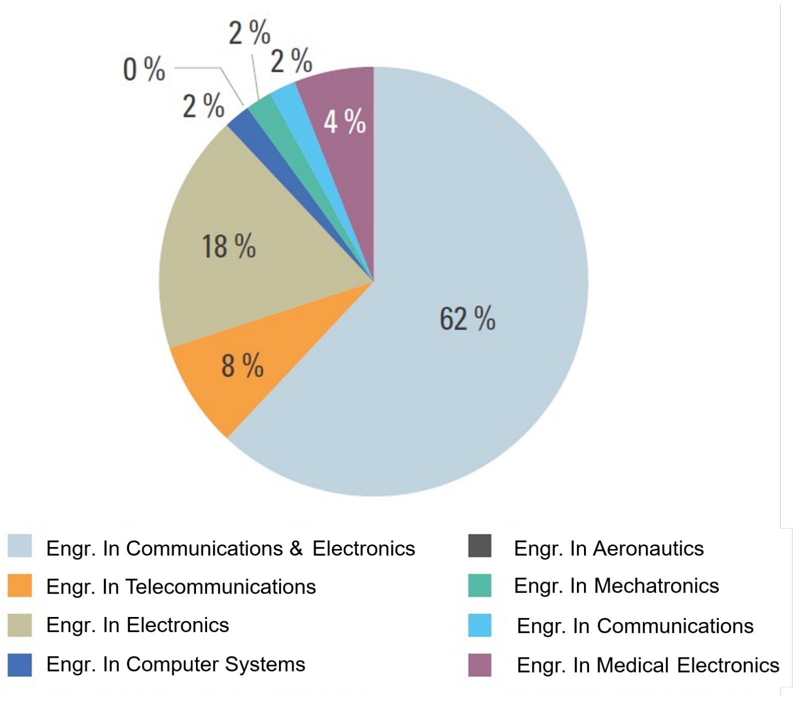

Figure 10: Professional studies of respondents

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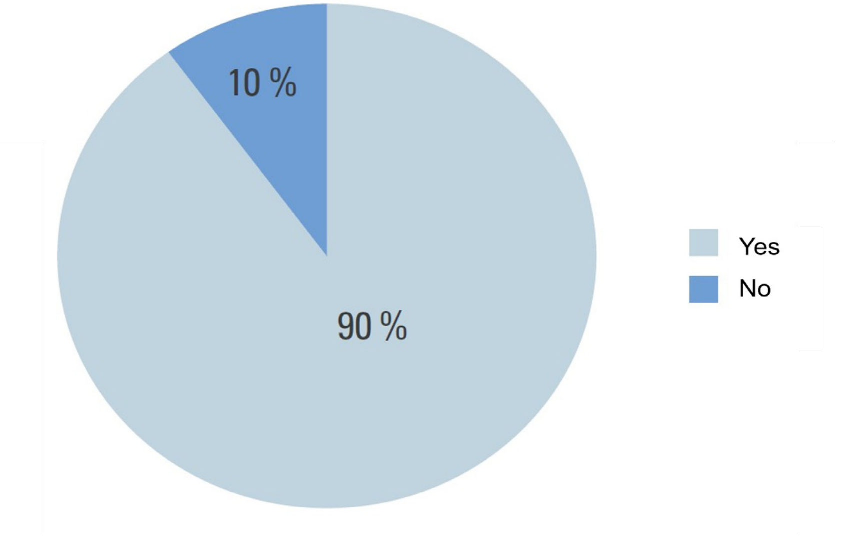

Figure 11: Do you consider your training geared towards developing competencies?

specialized?

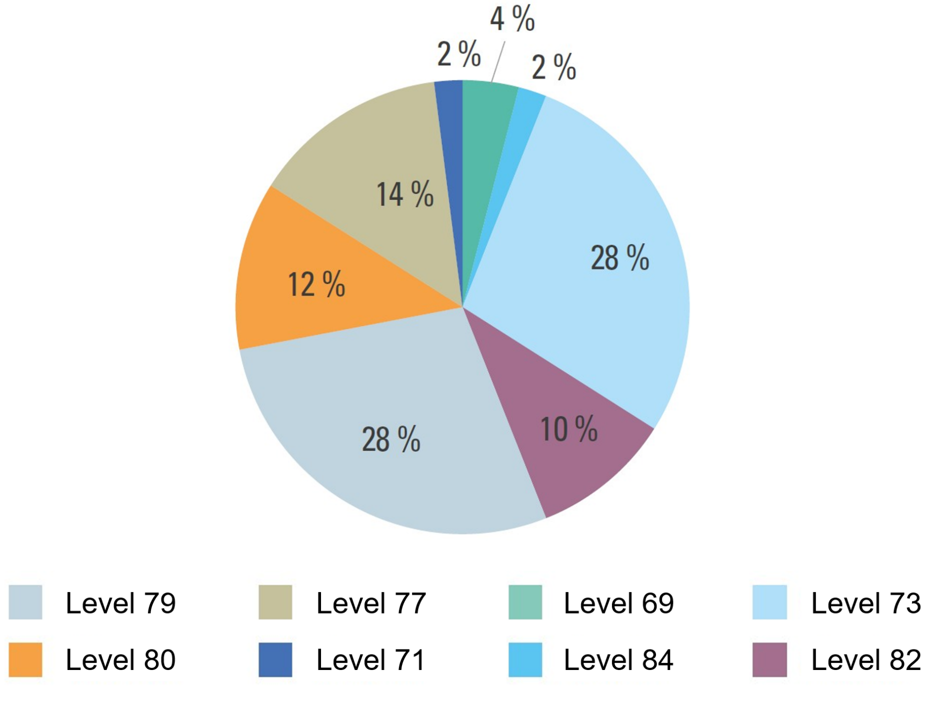

Figure 12: Meritocratic level

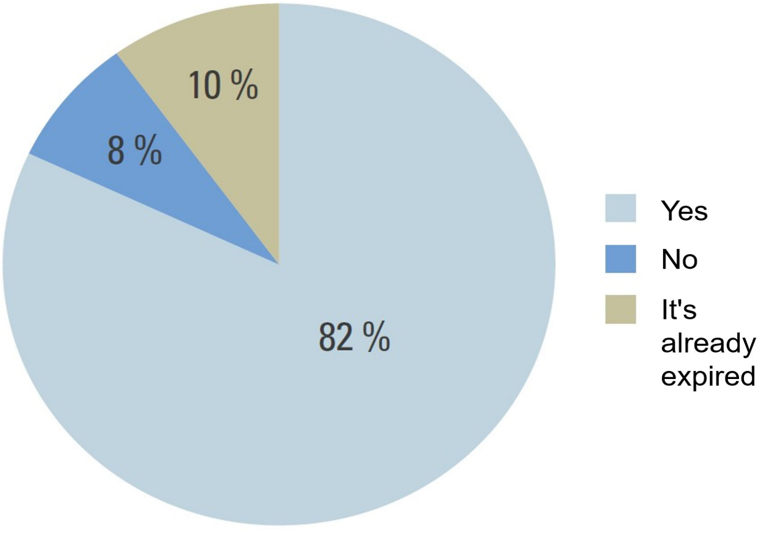

Figure 13: 13. Do you have an aeronautical license?

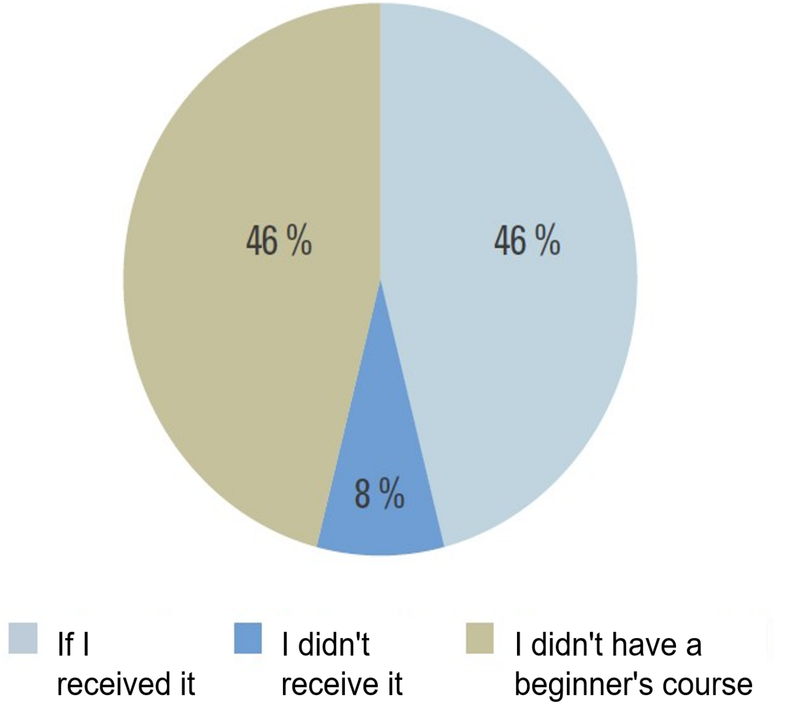

Figure 14: Did you receive a basic subject course in your initial training?

System	Duration (h)	Quantity	Percentage
VOR	280	20	40 %
DME	140	20	20 %
VCS	35	35	70 %
ILS	420	3	6 %
Modulation Transmission	35	43	86 %
Modulation systems	35	42	84 %
Antennas	35	40	80 %
Communications	35	39	78 %
Telephony	35	35	6 %
Radar	210	10	20 %
AFTN	35	33	66 %
VCS	35	35	70 %
VCX	35	28	56 %
DIVOS	35	33	66 %
Transmitters	35	32	64 %
NDB	35	2	4 %
Weather equipment	35	30	60 %
Satellite communication	35	32	64 %
Power Systems	35	44	88 %
Data Networks	35	22	44 %
Systems Training	35	16	32 %
Annex 10	35	44	88 %
ATOS	35	10	20 %
WAAS	35	1	2 %
LEITCH	35	8	16 %

Table 3: Training courses for IDS communications in general

ledge that exists in the an engineer with a different profile in his academic training, so that he can perform with better foundations within the aeronautical communications sector. In the first place, with 46% each, 23 engineers agreed for each answer "I did receive it" and "I did not receive it". Secondly, 8% (4 engineers) mentioned that they did not have an initial course.

Table 3 shows the training courses for engineers working in communications services, radio aids and radar engineering, specifically, the duration of their training courses for different aeronautical equipment and systems with the percentage of those who have received them.

CONCLUSIONS

Based on the results obtained, the learning curve of communications and electronics engineers working in the aviation sector at SENEAM was developed. Knowledge depreciates if there is no innovation and technology. Due to the lack of budgets or adequate strategic planning, according to Jacobs (2014), these could be decreasing, hence the importance of staying at the forefront in technological areas. A percentage of learning was considered according to the industry. According to Jacobs (2014), the percentage of learning index for the aeronautical sector of the airspace is 85%. There are differences between the learning index of an organization such as SENEAM in the field of aeronautical radio communications services and air traffic services and other industries that by convention handle another learning index. These differences occur due to the different characteristics of the operations derived from the equipment, the working methods, the services they offer, the organization of their productive plant and the differences in the procedures that are manifested in the development of the percentage of learning itself. In this research, the subject of study was personnel in the engineering area who have a career in Communications and Electronics Engineering (ICE) or related careers. According to Lefcovich (2003), a learning curve is the elaboration of a graphical census of the progress that occurs in the costs while The agency gains experience and increases the total number of artifacts produced on production or assembly lines. In order to know the answers to the variables, in this research a census was made of the progress in the training in which the engineers, through their courses, have accumulated hours of experience. The census was carried out through information collection tools such as surveys and interviews. In this way, the agency has gained with the experience curve or learning curve of its human capital and, in addition, in sectoral skills.

Determine the learning curve of the functions of the ICE in the aviation sector

a) Initially, it was known in which area the respondents work, the years of service for their projection and the percentage of knowledge about the job functions determined by the SINCO in unit group 2281 carried out by the surveyed ICE.

b) 80% of the forty respondents answered "yes, very good", and 20% answered "yes, good."

c) The functions involved in determining the learning curve in the ICE of the air sector in the SENEAM case were rectified. To this end, the activities that are needed to develop the learning curve on the training times of the equipment and systems in which the ICEs carry out their functions were described, as well as the "n" number of courses they have taken in their training within the agency.

d) With respect to the causes of the problem, and after an outline of the research approach, the following factors were established that determine the learning curve of the ICE in the aviation sector:

1. Work development.
2. Training.
3. Job functions of ICE.
4. Meritocracy in public administration.
5. National System of Classification of Occupations (SINCO).
6. Job satisfaction.
7. Work motivation.
8. Work teams.
9. Mentoring.
10. Sectoral competences.

d) To carry out the learning curve, data from the various systems that are used by the ICE of the air sector in SENEAM were used.

e) The logarithmic method was used to calculate the learning curve.

f) The collection of information to obtain the necessary data and make the calculations was done through surveys with the ICEs.

g) The calculation of the formula of the logarithmic method was carried out Various authors such as Krajenski (2000), Terrazas et al. (2009) and Jacobs (2014) indicate that the logarithmic method will facilitate the determination of the labor force for any unit.

Once all the data were known, the learning curve model was carried out taking into account the rate of the learning index which, according to Jacobs (2014), it is 85% in the airline sector. Thus, the learning curve was carried out and projected for each of the levels (69, 71, 73, 77, 79, 80, 81, 82) that exist in the labor categories of the ICE within the agency. It should be noted that the curve is applicable both individually and organizationally. On the other hand, learning that is acquired on an individual basis is the best outcome that would be expected from engineers who are receiving constant training because this process will give them the skills and efficiency by virtue of their own experience.

In the field of organizational learning, there are different types of training, but all of them, in the end, make up a single learning curve, where the knowledge that is being accumulated over a whole period is transformed into an intangible knowledge capital for the organization, but which contributes enormously to the learning curve of the organism. Throughout this process of the experience curve, knowledge, experiences, skills and skills are acquired. skills, that is, "practice makes perfect". The learning curve theory is based on three assumptions (Chango, 2014), which are proven in this research:

1. The amount of time required to complete a given task or unit will decrease each time the task is repeated.
2. The unit of time will decrease in a decreasing ratio.

Training received in the system	Number of engineers	Percentage (sample= 50)	Waiting time to receive the training	Y1		Nivel		69	Y2		Nivel		71	Y3		Nivel		73	Y4		Nivel		77	Y5		Nivel		79	Y6		Nivel		80	Y7		Nivel		82
Cantidad de años				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
RADAR	23	46 %	6 años						210 hrs																													
VOR	43	86 %	Menos 1 año	280 hrs																																		
DME	30	60 %	4 a 6 años				140 hrs																															
LOC	6	12 %	De 6 a 10 años						140 hrs																													
GP	6	12 %	De 6 a 10 años						140 hrs																													
IDME	6	12 %	De 6 a 10 años						140 hrs																													
NDB	4	8 %	10 años										35 hrs																									
VAISALA	31	62 %	11 años											35 hrs																								
VCX	25	50 %	9 años									35 hrs																										
VCS	38	76 %	6 años						35 hrs																													
LEITCH	8	16 %	1 año		35 hrs																																	
ATIS	10	20 %	6 años						35 hrs																													
AFTN	35	70 %	3 años			35 hrs																																
REDES	17	34 %	12 años												35 hrs																							
DIVOS	32	64 %	12 años												35 hrs																							
SATELITAL	37	74 %	4 años				35 hrs																															
TRANSMISORES	37	74 %	1 año		35 hrs																																	
RECEPTORES	37	74 %	1 año		35 hrs																																	
PBX	6	12 %	3 años			35 hrs																																
WAAS	1	2 %	10 años										35 hrs																									
"MATERIAS BÁSICAS: (Antenas, Tx Datos, Sistemas Modulación, y Comunicaciones)"	23	46 %	"A su ingreso 35 hrs x cada materia"	"4x35 140 hrs"																																		
"Cursos anuales 2 en promedio"	40	80 %	1	"2x35 70 hrs"																																		
"Curso de inducción (Curso de VOR y materias básicas)"	22	44 %	"A su ingreso"	420 hrs																																		
"Promedio de años para cambio de nivel (56% de 4 a 6 años)"				1				5					10					15					20					25					30					35

Table 4: Projection of the training of an ICE in SENEAM

X= Courses	K= Hours	Log B	Log 2	Log B/ Log 2	X Raised to N	Y
1	420	-0,070	0,301	-0,234	1	420,00
2	140	-0,070	0,301	-0,234	0,85	119,00
3	70	-0,070	0,301	-0,234	0,77	54,104
4	35	-0,070	0,301	-0,234	0,72	25,287
5	35	-0,070	0,301	-0,234	0,68	23,998
6	35	-0,070	0,301	-0,234	0,65	23,994
7	35	-0,070	0,301	-0,234	0,63	22,177
8	35	-0,070	0,301	-0,234	0,61	21,494
9	35	-0,070	0,301	-0,234	0,59	20,908

Table 5: Learning Curve Calculation Data for Level 69

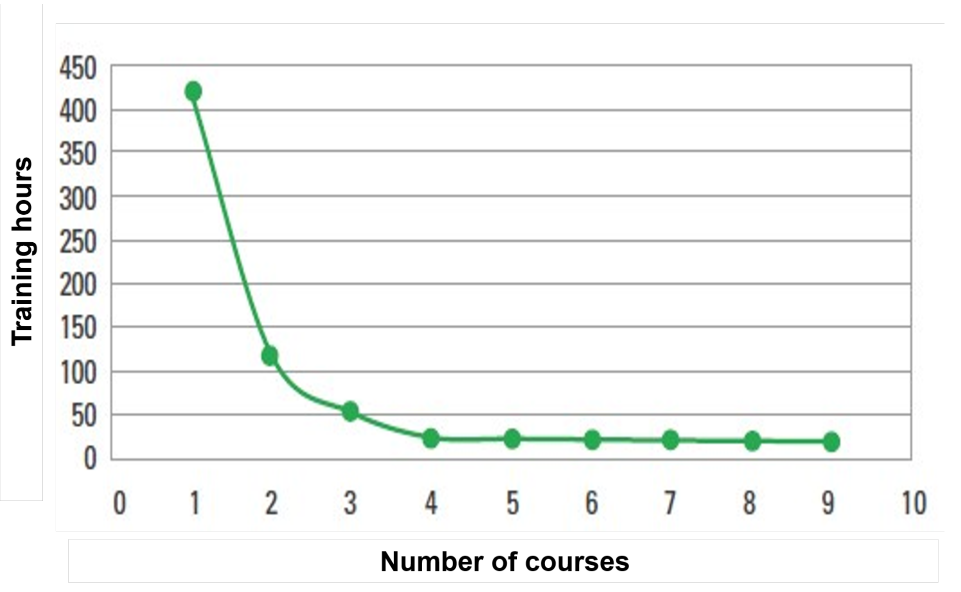

Figure 15: Level 69 learning curve

Basic sciences	General knowledge	Engineering knowledge	Skills and values
Mathematics	Administration	Electronic circuits	Decision-making
Physics	English	Signal Processing	Professional ethics
Programming	Resource Management	Analog electronics	Professional ethics
Electromagnetic theory	Computer systems	Digital Electronics	Liability
Antennas and propagation	Measuring Equipment	AM-FM Modulation Systems	Teamwork
		Radio ayudas	
		Ground-to-air communication	
		Power Systems	
		Communication networks	
		Digital telephony	
		Satellite communications	
		Wireless communications	
		Aeronautical networks	
		TCP-IP networks	

Table 6: Knowledge for the ICE profile of the aeronautical sector

3. The reduction in time will follow a fixed pattern.

Table 4 shows a projection of the learning curve through the training of the ICE in SENEAM, according to the data collected both in the surveys and in the interviews with IDS staff, who have been staff with success stories. In addition, samples were taken from all regions of the country that make up the organism. This projection table was used for the realization of the learning curve.

Table 5 presents the data for the calculation of the learning curve of ECIs with level 69 using the logarithmic method. This is a starting level for an engineer who has recently joined the agency in the area of IDS communications, radar and radio aids. The data in the column K=Hours and N=Courses were obtained from Table 4 on the projection of ICE training in SENEAM. This is the case with all the calculations of the learning curves at all levels. Table 4 of the projection shows that it is in accordance with the meritocracy and training of each level of the ICE.

Figure 15 shows the learning curve of level 69, where training courses are accumulated during their beginnings in the organization within 4 to 6 years.

It is observed that the curve descends from left to right and indicates that experience lowers costs as production or learning increases. Costs will decrease more slowly than accumulated experience; this means that as time goes by and the experience of the equipment and systems matures, it becomes more difficult to reduce costs, because little by little the expenses in training are reduced by the experience that is acquired at the time of training appropriate to the entry of an ICE to the agency.

The abscissa axis (Y-axis) measures the cumulative number of time spent in ICE training during entry to work at the agency. The ordinate axis (X-axis) measures the number of training courses needed to achieve the learning curve. It is concluded that the learning curve is atypical, since no curve is completely uniform, since there are always fluctuations in its inclination and other factors that influence its determination (Yelle, 1979; Titone, 1986; Kelly, 1982). The learning curve was tested as proposed by Wright (1936). In it there is a steep slope that indicates hard and difficult learning, while as it becomes flat it indicates easy and efficient learning; on the X axis the accumulation of what has been learned is observed and on the Y axis the time invested.

Profile of the communications and electronics engineer in the Mexican air sector

As a result of the research carried out, a profile of the communications and electronics engineer who works in the aeronautical sector of Mexico was obtained. Their competencies and how meritocracy influences their development were found. The determination of the learning curve made it possible to know the profile of the ICE of the air sector, which will be proposed to be used by SINCO in 2021 in the catalog of positions, with the description and functions performed by engineers in the air sector in Mexico. Likewise, a profile was developed that includes the knowledge, values and skills that are related to the basic knowledge that is available at the beginning of the engineer's training, and that are necessary within the aeronautical sector if the working conditions are taken into account for the solution of the problems detected in aeronautical systems and equipment (see table 6).

Sectoral competencies are developed according to the training being received while assimilating the technological changes that exist in an accelerated manner in the aeronautical industry.

According to the basic sciences

1. Mathematical knowledge and skills for the performance of different calculations necessary in electrical measurements.
2. Knowledge of physics to perform different calculations related to the use of vectors used in the training of radio aid equipment.
3. Programming knowledge for the design of systems and electronic interfaces.
4. Knowledge of electromagnetic theory for the understanding of electrical and magnetic phenomena used in electronics and communications.

According to general knowledge

1. Management knowledge to keep the activities that are carried out in order and under control.
2. Knowledge of a foreign language such as English, as it is the world language of aeronautics and is required for training, coordination, testing and documentation of equipment and systems.
3. Knowledge of antennas and propagation. Antennas are required to receive and emit electromagnetic signals; When transmitting or receiving, they propagate electromagnetic signals through various means.
4. Knowledge for the management of both financial and human resources to carry out the various projects.
5. Knowledge of computer systems for the management of the various software and hardware used in the airline industry.
6. Having the ability to work in a team helps to share knowledge and stimulates
7. Knowledge of electrical circuits for the knowledge of the transport of electrical energy through wiring and electronic devices.
8. Knowledge of analog and digital signal processing to know a mathematical manipulation of an information signal, to change or improve it in some way, and is used in various voice processing and communications equipment.
9. Knowledge of analog electronics for the management of voltages, currents, resistors, impedances, power.
10. Knowledge of digital electronics for discrete components used in electronic equipment.
11. Knowledge of AM and FM modulation systems for use in radio electrical communications in various aeronautical equipment and systems.

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12. Knowledge in radio aids for equipment such as the Locator, GP or Glide Path, IDME, VOR, DME, NDB.
13. Knowledge of ground-to-air communications, which is carried out through radio equipment on aeronautical frequencies and is necessary for communication between air traffic controllers and aircraft pilots, as well as tower controllers with ground personnel.
14. Knowledge of electrical power systems for the supply of energy provided by the operation of aeronautical and communications equipment.
15. Knowledge of data communications networks for sending and receiving information through various means such as fiber optics, terrestrial, antennas and internet protocol links.
16. Digital telephony knowledge for voice recorders and voice links.
17. Knowledge in satellite communications for voice and data links used in a national network.
18. Knowledge of microwave systems used in voice transmission and data links for networks or monitoring of aeronautical equipment.
19. Knowledge of wireless links, which facilitate operation in places where computers or other devices are not in a fixed location.
20. Knowledge of aeronautical networks for the exchange of information in the global aeronautical network such as AFTN.
21. Knowledge of TCP-IP networks, which are used in the operation by providing communication between computers and servers or the Internet.

According to skills and values

1. Decision-making skills to make a choice between options or ways to resolve situations that arise.
2. Ability to perform analysis and be able to process information that helps make the best decisions to obtain good results.
3. Maintaining professional ethics is important to conduct oneself in accordance with the norms and values that govern the actions of a worker in the organization and to work together for the common good.
4. Maintain responsibility to have a level of commitment that is assumed by the staff to achieve a better position in the organization.
5. Maintaining teamwork is required in the various tasks to share common activities that are designated, in such a way that the safety of the team members is taken care of and the assigned objective is achieved.

Elements that influence the formation of a learning curve

a) Age.

b) Knowledge of the functions of the work to be carried out.

c) Empathy to learn.

d) Ability to concentrate.

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e) Talent of the individual.

f) Process design.

g) Continuous improvement methods or *kaizen*.

h) Work materials or tools.

Risks of being indifferent to the learning curve

In an organization, the learning curve is considered essential for the development and training of engineering personnel, due to the risks that exist in the functions of the ICE (Acá, 2017).

When personnel are not well trained, they are susceptible to making certain mistakes that affect the work to continue carrying out projects.

1. It could cause damage to the projection in the aeronautical sector, due to errors that impact the image of the organization; that is not beneficial.
2. Carelessness due to lack of training that could cause an ICE to put the safety of people on an aircraft and their lives at risk because they have not been properly trained in the handling of certain air navigation systems and equipment.
3. Increase empathy for the operation through new signs, feedback on safety procedures, equipment and systems where ICE could be at risk of an accident.

Benefits by improving the learning curve

a) Productivity improves if time is reduced and the mechanics of adaptation of new personnel are perfected.

b) Attraction and retention of employees, as workers are more interested in a job where there is a starting point.

c) It increases the competitiveness of companies that have learned to control turnover and absenteeism.

d) Growth of the organism.

e) Generate employee loyalty. By maintaining clear communication channels, the defined processes feedback and work engagement will surely be achieved.

f) Reducing costs by increasing training and production.

Sectoral competencies that predominate in the ECIs in SENEAM

The majority of the surveyed ECIs stated that having a specialization in their functions will encourage them to develop their sectoral competencies, acquire knowledge, increase skills; Having feedback courses will favor them with faster and more efficient learning that will help them have less time wasted when performing their work functions.

Sectoral competencies are a basis for optimizing the employability of ECIs, due to the knowledge obtained in the face of a specific task, which becomes unquestionable when the ECI enters into a deal with it. Competence will admit the knowledge, knowledge and skills that are born from the interaction that is going to be between the

ICE and the task. Sectoral competences are a comprehensive training focus point that will connect the world of work and ECIs with education, focusing on the perfection of human capital as a principle of innovation, knowledge, differentiation and competitiveness by admitting to bring together (make available) different knowledge in a certain argument in order to solve professional contexts.

The competencies:

1. They manifest complex and integrated capabilities,
2. They are related to knowledge (theoretical, contextual and procedural),
3. They are linked to know-how (formalized, empirical, relational),
4. They refer to the professional context (understood as the situation in which the professional must perform or practice),
5. They refer to the professional performance that is intended (understood as the way in which a technically competent professional acts, and socially engaged),
6. They allow ethics and values to be incorporated.

The aeronautical technical personnel trained in courses endorsed by the AFAC are authorized to perform the intervention of "electronic ground systems and radio aids" to air navigation and have their accreditation of courses for radar systems.

The following sectoral competencies of the ECI in SENEAM were defined in the instrument, which are derived from the functions of the unitary group 2281 of the SINCO (CONOCER, 2017). As stated by Miro (2009), sectoral competencies are classified into transversal or generic competencies, technical competencies, and sustainability and innovation competencies, which are related to the technical knowledge acquired in their training by ICEs with the different equipment and systems in the aeronautical area with the different equipment and systems. As described by CONFEDI (2016), a competency is the ability to efficiently enunciate a set of sketches (mental arrangements) and values.

Sectoral competencies of the ECIs in SENEAM

1. Competence to effectively use engineering techniques and tools to solve technical failures in aeronautical communications equipment, voice/data networks, aeronautical radionavigation, satellite communications, radar equipment and systems.
2. Ability to monitor, evaluate and adjust the operating process in aeronautical communications equipment, meteorology, aeronautical networks, radio aids, satellite systems and radar systems.
3. Ability to control the process of installations of aeronautical communications equipment, antennas, voice/data networks, meteorological equipment, air navigation systems and radar systems.
4. Ability to identify, formulate and resolve failures of communications systems, meteorology systems, remote monitoring systems.

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5. Ability to prepare reports and documentation with technical specifications derived from facilities, changes and services generated.
6. Ability to incorporate the application of official and technical standards relating to aeronautics.
7. Ability to control the activities in process of installations and other services carried out.
8. Ability to prepare specifications, diagrams, drawings to make recommendations in aeronautical communication systems.
9. Ability to optimize teamwork in coordination with external personnel in the various activities required in the services.
10. Ability to manage and control procedures for the implementation of installations, maintenance of communication equipment and aeronautical networks.
11. Ability to manage contributions and financial resources for aeronautical technology projects.
12. Ability to develop technical reports regarding the operation of aeronautical equipment and systems.
13. Ability to develop projects by identifying the technologies available in the market.
14. Ability to design standards for the control and good service of systems.
15. Ability to perceive and direct systems development activities.
16. Ability to perform a search for the implementation of aeronautical systems.

The sectoral competencies were the result of the application of the survey in the instrument and were based on the functions to be performed by the ICEs, which are defined by the SINCO group 2281. These sectoral competencies are obtained through training. Salgado Benítez (2006) exposes them as a use of knowledge, mainly of a technical, scientific and administrative nature. In the development of the ICE in the aeronautical sector, these are obtained through the courses that are conferred on them to achieve the necessary knowledge and skills.

92% of ECIs believe that they have the essential knowledge to carry out their functions, but they express the need to provide more knowledge. Most of the respondents said that having a specialty in their functions will help them to develop their sectoral competencies, increase skills; likewise, having a faster and more efficient learning will help them to have less time wasted when performing their work functions.

As Hitt (2008) mentioned, growth skills arise from analysis from the inner environment. This means the use of their own resources and capabilities, which will be where the main competencies will be perceived, and where the competitive profiles of the functions of communications and electronics engineers in the aviation sector will be developed (Klim, 1993). Chango (2014) points out that Wright's guesses about the learning curve were that "the man-hours needed to complete a unit of production would decrease by a constant percentage each time production doubled." This implies a greater production by an ECI each time its training and training improve along with its deve-

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loped experience, skills and sectoral competencies, which generates a benefit for the agency through a reduction in production costs as well as in its training by achieving an improvement in the learning curve.

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