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The Evolution of Teaching Geomatics at the Polytechnic School of University of São Paulo

A Evolução do Ensino de Topografia e Áreas Afins na Escola Politécnica da Universidade de São Paulo

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Abstract: The determination of the relative position of points and the graphical representation of the Earth's surface, among other knowledge of Topography and related Sciences, is present at different moments in the professional practice of civil engineers. At the Polytechnic School of the University of São Paulo (EPUSP), teaching Land Survey has been taking place since the School's Foundation in the late 19th century. After this period of more than a century of teaching survey at EPUSP, scientific, methodological, and technological developments have occurred. These developments drove changes in the structure of the School and the University, in Higher Education and the social and political context, generating new needs and demands from society, requiring engineers and surveyors to adapt to the new demands and possibilities. Facing these evolutions came Geomatics, which includes Land Survey and related areas in the era of technology and information technology. For the teaching of Geomatics, there is a constant challenge of adapting to evolutions and changes. Thus, the objective of this work is to present and discuss the evolution of Land Survey teaching at EPUSP, in the face of scientific, methodological, and technological changes and evolutions. At a time when changes and innovations in the world occur at an increasingly accelerated pace, there is a need for discussion about teaching and the use of technologies and fit to changes and evolutions ruled on teaching based on the importance of permanent concepts facing constantly changing technology.
Keywords: Higher Education. Technology. Land Survey. Geomatics. Innovation.

Resumo: A determinação da posição relativa de pontos e a representação gráfica da superfície terrestre entre outros conhecimentos de Topografia e ciências afins está presente em diferentes momentos do exercício profissional de engenheiros civis e de outras modalidades. Na Escola Politécnica da Universidade de São Paulo (EPUSP) o ensino da área acontece desde a fundação da Escola no final do Século XIX. Ao longo desse período de mais de um século de ensino de Topografia e ciências afins na EPUSP ocorreram diversas alterações que impulsionaram mudanças na estrutura da Escola e da Universidade, na Educação Superior e no contexto social e político gerando novas necessidades e demandas da sociedade, exigindo que engenheiros e profissionais da área da Topografia se adaptassem às novas demandas e possibilidades. Frente a essas evoluções surgiu a Geomática que engloba a Topografia e áreas afins na era da tecnologia e da informática. Para o ensino da Geomática há o constante desafio da adequação e adaptação às evoluções e mudanças. Desta forma, o objetivo deste trabalho é apresentar e discutir a evolução do ensino de Topografia na EPUSP frente às mudanças e evoluções científicas, metodológicas e tecnológicas. Em um momento em que as mudanças e inovações no mundo ocorrem em ritmo cada vez mais acelerado, há a necessidade da discussão sobre o ensino e a utilização das tecnologias e adaptação às mudanças e evoluções pautada e embasada pelo ensino fundamentado na valorização dos conceitos permanentes, frentes à tecnologia em constante mudança.
Palavras-chave: Ensino Superior. Tecnologia. Topografia. Geomática. Inovação.

1 INTRODUCTION

Land Survey played an important role in the mapping of the territory and the development of Brazilian

Engineering. The Polytechnic School of the University of São Paulo (EPUSP), since its foundation in 1893, sought to be at the forefront of engineering development and engineering education.

The teaching of Land Survey in this school has been present since the beginning, passing through various educational regimes and policies. The Polytechnic School, together with the School of Law and the School of Medicine, were integrated for the foundation of the University of São Paulo (USP) in 1934. It has adapted to the new university models, especially after the changes brought about by the reforms of the Vargas dictatorship and the university reform of 1968 and later by the changes in the curricular structures (EC) 1, 2 and 3 (LOSCHIAVO DOS SANTOS, 1985; BALBO, 2017; BRAGGIO, 2019).

It also has adjusted to the changes in science and surveying technology that have occurred during this period. In the area of Land Survey, several developments took place in field equipment, pre and post data processing resources, and mapping. The School was able to reconcile tradition and modernity, emphasizing permanent concepts and methods in the face of the mutability of concrete equipment and techniques.

At the end of the 19th century, Land Survey was based on tachymeters, theodolites, levels, chains, and tapes, with extensive use of analogical equipment (optical-mechanical), the only ones existing at the time. The main works were connected to surveys for the construction of railroads, land parcels (allotments), maps, and determination of coordinates of the territory. They were therefore completed with astronomical and geodetic measurements, also taught at school, with a practical character (CINTRA, 1993).

During the first half of the 20th century, optical-mechanical equipment, such as levels and theodolites, gradually improved in precision, installation, and reading processes, size, and weight. The chains of surveyors evolved into tapes New techniques and processes emerged and consolidated themselves, such as aero photogrammetry, the use of cartographic projections, highlighting the Universal Transverse of Mercator (UTM) for use in engineering projects. There have also been evolutions in the knowledge and determination of the geoidal surface and characterization of the ellipsoid (WOLF, 2002).

In the last quarter of the 20th Century, there was the popularization of computer science, electronics, and computer graphics. Electronic instruments like the Electronic Theodolite and the Electronic Distance Meter (EDM) appeared, which integrating themselves gave rise to the Total Station. This, in addition to measuring angles and distance in a single instrument, allows the data to be stored through an electronic field notebook and then electronically processes this data in computers. Also became popular personal computers, calculation programs, data processing and computer aided design (CAD - Computer Aided Design), evolving to programs directly applied to Land Survey (Digital Terrain Modeling, Database, Digital Cartography, and Geographical Information System), with an interface to programs aimed, e.g., at Road Design.

At the end of the XX Century and beginning of the XXI Century new methodologies, technologies and sciences have emerged and consolidated themselves, such as the Global Navigation Satellite System (GNSS), Remote Sensing, Digital Level, Terrestrial and Aerial Laser Scanner Systems, Remotely Piloted Aircraft (RPA) or Unmanned Air Vehicles (UAVs). These new features allowed greater agility, shorter processing time, through process automation, in addition to allowing working with a greater volume of data and information (SILVA, 2020).

In the field of education, the changes happened in parallel. Besides the blackboard and chalk, we moved on to projections in transparency and after computers, allowing digital projections and classes in a computer lab: that is, new educational tools for teaching the subject.

This paper has the purpose of presents and discusses the evolution of Land Survey and its teaching from the evolutionary understanding of Topography and related disciplines teaching at EPUSP, from its foundation until the end of the second decade of the XXI Century. Intends to discuss and understand the changes and impacts that technological and scientific advances, throughout this period, have provided in Land Survey and its teaching, as well as to analyze the contributions to this area, in the State and the country, taking into account the graduation and, mainly, the Graduate Program in Transportation Engineering, looking at the Spatial Information Research Line with emphasis on Topography, Geodesy, and Cartography.

Finally, it aims to analyze the didactic process, which started to value concepts more than the concrete techniques of equipment operation in Engineering Education. The emphasis on conceptual aspects does not imply or exclude looking at techniques, instruments, and their technological advances. Thus, what is defended, in the face of the growth of technologies and contents and the reduction of the workload, is the focus on concepts, less subject to change.

2 THE TEACHING OF TOPOGRAPHY AT EPUSP

Since its foundation, EPUSP has tried to keep up with the demands of society, the improvement of sciences and technologies, keeping its protagonist and vanguard in the training of engineers. Throughout this more than a century of history, as pointed out, the teaching of surveying has been present and transformed over time suffering the impact of scientific, methodological, and technological developments in the area and internal institutional changes. This item summarizes these changes and the evolution of the discipline of Topography at EPUSP. Finally, it seeks to establish a connection between the evolutions through its analysis in a timeline.

2.1 Scientific, Methodological and Technological Developments in Land Surveying

Land Survey is defined as "the applied science that studies the methods of representing a terrain (a part of the Earth's surface) for project planning and design" (CINTRA, 2012). This is a more practical definition of Surveying, which deals with its application in Engineering area.

However, Surveying, Engineering, and the world have evolved. The needs of society have also become more challenging and implying more complex, interdisciplinary, and integrating solutions. In this way, the area of Geomatics was created to encompass several areas of knowledge of Earth space, such as Topography, Geodesy, Cartography, and Computer Science applied to them.

When EPUSP was founded, Surveying was based on tacheometers, transits, theodolites, and optical-mechanical levels. In related areas of Land Survey, such as Geodesy, the end of the 19th Century was a moment of important conceptual advances that would later enable the development of several technologies, especially those using electromagnetic radiation. It was also a period of consolidation of the geodesist profession and with the contributions of Gauss and Helmert (IHDE; REINHOLD, 2017).

In Brazil, more specifically in São Paulo, the end of the 19th Century was a time of the beginning of demographic growth due to immigration, industrial development in the capital of São Paulo, and the expansion of agriculture with the consequent occupation of the territory. Infrastructure works, mainly the construction of railways that linked the interior of São Paulo to the capital, and the Port of Santos, to export coffee, had surveying as support (CAMPOS, 2007; CAMPOS; GITAHY, 2009; PADILHA, 2010).

It was in this context that the Polytechnic School was founded, with a vision of the practical application of Engineering to drive development, based on the philosophy of the German Polytechnic Schools (ETH - Eidgenössische Technische Hochschule), essentially applied, as opposed to the Polytechnic School of Paris, the model of the Polytechnic of Rio de Janeiro, that emphasized the theoretical foundations of engineering.

At the time of its foundation, the School had modern equipment for the time: theodolites, tacheometers, transits, and levels that were used in practical classes of Topography, Geodesy, and Field Astronomy disciplines. In the year following the opening of the School, its founder, Antônio Francisco de Paula Souza, published the book "Elements of Tacheometry: cleps, description and practical use of this instrument" (SOUZA, 1895).

At the beginning of the 20th Century, the evolution continued at the same rate as at the end of the previous century, with some ideas still emerging in the field of theories and concepts that would be developed in the 20th Century and the beginning of the 21st Century.

Significant changes and developments in land surveying and related sciences, as well as in the entire field of engineering, occurred during the period of the two world wars, with the military industry seeking solutions to improve the quality and speed of obtaining information about the earth's surface, as well as determine the position and facilitate navigation (HARTCUP, 2000). Developments occurred in the areas of aerophotogrammetry, use of EDM in distance measurements, use of cartographic projections, and references. Surveying instruments became more and more portable, with devices that provided speed in their use and increased accuracy of data obtained in the field, with great emphasis on German and Swiss companies such as Wild, Kern, and Zeiss. The EPUSP had theodolites from these producers; however, at that time, the instrument most used for classes and fieldwork was the Keuffel & Esser theodolite, of North American origin (MANIERO; VANDERLINDE, 1954).

In Brazil, in 1941 DF Vasconcellos was founded, a Brazilian company of optical instrumentation that developed equipment for the Brazilian army and, in Land Survey, developed theodolites widely used in the national territory (SOUSA; ROSAS, 2019). The development of some instruments by DF Vasconcellos happened in partnership with EPUSP, which started to use these theodolites in classes and fieldwork in the 1970s (CINTRA, 1993).

In the middle of the 20th Century, with the beginning of the Cold War, the evolutions and transformations started to occur at an even faster. It was during this period that the development of electronics, telecommunications, and computer science began to gain strength and thus instruments for various purposes that integrate these emerged technologies.

In the area of Land Survey and related sciences the development of Remote Sensing and GNSS, the development of digital terrain models, electronic levels, electronic distance meters (MED), electronic theodolites and electronic notebooks that through their integration, gave rise to Total Stations can be mentioned. Computational resources also developed that allowed calculations, data processing, and computer-aided drawings and designs (WOLF, 2002; SCHERER; LERMA, 2009).

Another important point of this period was the standardization of systems and references, for example with the adoption of Greenwich as the meridian of origin (this, since the end of the XIX, with its effective implantation at the beginning of the XX), the recommendation of adoption UTM projection, in the middle of the XX century, factors that contributed to the international cooperation and the beginning of globalization in Surveying and related areas.

The end of the 20th century and the beginning of the 21st century mark a new era in which information has started to spread faster and faster with the development of the internet, personal computing, and mobile phone, creating an environment conducive to the emergence and development of the digital world. In the field of Topography and related areas, the instruments started to count more and more on technology and embedded electronic components, allowing robotization, remote control, and obtaining and manipulation of an increasing volume of digital data. The launching of equipment with incrementation and technological innovations started to happen at a vertiginous pace, making obsolescence happen more quickly.

2.2 Evolution of Land Survey Teaching at the EPUSP

In the program of Civil Engineering, to follow the evolution of technologies, regulations, legislation, and educational policies advanced, providing changes that are analyzed in the sequence.

Throughout its history, the EPUSP has undergone 15 regiment changes. Some have had little influence on the teaching of the land survey; however, others have had a great impact. The change of regiment influenced by the foundation of the University of São Paulo in 1934 provided some structural changes in the School (GOLDEMBERG, 2015); however, as far as the subject of Surveying and its teaching was concerned, they were smaller. Years earlier, in the late 1910s and early 1920s, the removal for health reasons of the professorship lens of Land Survey, Dr. João Duarte Júnior, who had been replaced by Dr. Lúcio Martins Rodrigues, brought changes and developments of greater influence to the teaching of this discipline.

Professor Rodrigues, former director of the School and principal full professor (*catedrático*) of USP, together with his colleagues Francisco Behring and Rogério Fajardo, were precursors in the teaching of Astronomy in São Paulo. Rogério Fajardo published, in 1907, in "Revista Polytechnica", a study on the evolution of geodesy divided into 6 parts. Professor Rodrigues was responsible for the project of the Astronomical Observatory of the EPUSP in Buenos Aires Square built-in 1933 (SANTOS, 2014): a place and observatory in São Paulo, that were used for classes and surveying fieldwork. About the land surveying classes, he promoted changes, the inclusion of content: approaching the theory of errors as an independent and important topic for Land Survey; approaching new cartographic projections; using Keuffel & Esser theodolites in practical works; project setup; and exploring Geodesy and Astronomy (RODRIGUES, 1923).

They were also *lenses* or teaching assistants in Topography at EPUSP until the 1960s. Henrique Jorge

Guedes, Paulo Ferraz de Mesquita, and Francisco Salles Vicente de Azevedo, who continued the new contributions to teaching. In this field, mainly professor Mesquita contributed with publications of texts in the field of astronomy in editions of the "Polytechnica" magazine (MESQUITA, 1934), a book on Land Survey (MESQUITA, 1969) and his thesis on the instrument level-diastometer (MESQUITA, 1959), in addition to analyzing and recommending a technical book on Land Survey for the Ministry of Education and Culture (MEC) (MESQUITA, 1966).

About the fieldwork, it is necessary to emphasize the importance of these classes in the learning and consolidation of concepts of Topography. To execute a land surveying, from its planning to the engineering project, passing through the several stages of the work, is a rich and complete exercise for the formation of the Civil Engineer. Even if these professionals, for their most part, do not come to work directly with Surveying, the knowledge in the area and a minimum about the nature and operation of equipment is important.

For this reason, a lot of importance has always been given to what for a long time has been called a *vacation exercise* and currently is called the *final project*, which aims to allow the student to have this experience (CINTRA, 2012). The area for this survey has varied over time: Campos do Jordão, areas near the Pacaembu Stadium, Buenos Aires Square, Campus of USP, in general, around the Civil Engineering Building, or even freely chosen by the groups.

The main transformations in teaching were linked to the change of the full professor (chair), a system that governed the Brazilian Universities and Colleges. The masterclasses (magistrals) were given by this professor and the practices by the lenses and assistants.

This system changed in the 1960s, when a series of reforms in the Brazilian higher education model promoted by the military government took place. This moment came with the 1968 University Reform (BRAGGIO, 2019), which created conditions for Teaching and Research to be more articulated within the institutions; the lifelong chairs regime was abolished introducing the departmental one, the teaching career was institutionalized, including admission and career progression through academic qualifications: assistant, master, doctor, assistant and titular (full professor), in use until today, with slight changes (MARTINS, 2009).

At EPUSP, the reform was implemented in 1971/1972, years in which the departments were created. Topography, for a short period, was linked to the Hydraulic Department (PHD, currently PHA - Department of Hydraulic and Environmental Engineering), remaining, later and until today, linked to the Transportation Engineering Department (PTR).

In this reform the classes and chairs regime were extinct and the disciplines that were linked to then were transferred to the departments. Another important change was the concentration of efforts and optimization of resources: the basic subjects (Calculus, Physics, Law, Portuguese) were now taught by the Institutes of Mathematics, Physics, Law School, and Languages). Concerning Land Survey, the Polytechnic and the PTR were allocated the professors of Architecture (FAU), Geology (IG), and Mining Engineering (PMI - Department of Mining and Oil Engineering), with 4, 2, and 2 professors, respectively. The annual regime, with an average of 7.0 (over 10) approval in the normal period, was replaced by the half-year regime, with an average of 5.0.

Until the reform, the teaching of Surveying and related areas occurred, most of the time, in two chairs and one class: The Topography class and the Geodesy and Astronomy class, both lasting one year, and the Topographic and Cartographic Design class with the same duration. From the reform were created the subjects of Land Survey I and Land Survey II, each one with a four-hour class load and duration of one semester. There was thus a reduction in the workload, together with the insertion of new contents due to the technological changes that occurred.

In the 1970s, as part of the reform, the Post-Graduation course began, also thinking about training and teaching career. This led to an increase in research at the master's level (started in 1976 at PTR) and doctorate level (started in 1983), with the production of dissertations and thesis. As time went by, some professors finished their Ph.D. program and new professors started to be hired, at least with a master's degree; having several of them spent some time in Universities abroad. All this had a very beneficial influence, raising the level of undergraduate classes, and providing the introduction of new concepts, such as Digital Terrain Model (MDT), Computer Graphics, Computer Aided Design (CAD), Digital Cartography, UTM Projection Systems, renewal of Aerophotogrammetry, and Geographic Information Systems (GIS), for teaching the area, at undergraduate and graduate levels.

Since the late 1990s with the changes and developments in Information and Communication Technologies (ICT), Higher Education Institutions have gone through changes and are still experiencing a moment of adaptation to this new reality (LEITE; RIBEIRO, 2012). Informatics and electronics have been consolidated in the teaching of Topography, whether using audiovisual resources or specific Topography software in the classes or in the use of Surveying instruments with embedded electronics.

As far as the subjects of the area are concerned, in the 1990s they were called Spatial Information I and II, with a reduction of two hours in the second subject. This reduction was due to the introduction of the discipline of Geoprocessing. The creation of this discipline had the contribution of Prof. Dr. Marcos Rodrigues when returning from a period of studies in England and publication of the thesis of *Livre-docência (a previous steep for full professor)* on Geoprocessing (SOUSA et al., 2004).

Following the evolution of the area, in 2015, the curricular components were renamed Geomatics I and II. To help face the reduction of workload and allow the deepening of knowledge to students with interest in the area, optional disciplines on cartographic projections, satellite positioning, and geoprocessing were created. There was also the extinction of the 2nd discipline (2 credits), due to the philosophy of Curriculum Structure 3 (EC3) reform. This change had the objective of leaving a formation characterized by a strong specialization with roots in 1980's guidelines (Curriculum Structure 2) to a broader, generalist and flexible conception of formation, introducing the contact with Engineering and specific qualification disciplines in the 1st semester of the course (AMARAL, 2014; BALBO, 2017). For this reason, Geomatics I began to be worked on as soon as the 1st Semester of Civil Engineering. The transformation of Geomatics II was also due to a guideline to reduce the workload of the mandatory subjects.

As for the surveying instruments used at EPUSP between the end of the 20th century and the beginning of the 21st century, it should be noted that MED, automatic level, digital level, electronic theodolite, total station, GPS navigation receiver - Global Positioning System, used in the practical classes, were acquired. Most of these instruments were acquired in quantity to be used in practical classes with fieldwork, for all students, while others had the acquisition of a few copies (often only one or two) to be used more intensively at the research level in graduate studies and to illustrate some undergraduate classes. Specifically, digital level and geodetic GNSS receivers were acquired to serve more research, but mobile receivers (one for a group of 3 or 5 students) were used in one or two field classes. Later, in the second decade of the 21st Century, more advanced and more accurate equipment was purchased, such as total stations with laser plumbing (in quantity to be used in practical classes), total robotic station and laser scanner (only one of each to be used in research and for illustration in classes).

The purchase of a few instruments of a specific kind is linked to the low need and frequency of use in undergraduate classes and the need for one or two copies for research at the graduate level. The only exception is the digital level, which would only be used in a single practical class during the whole course and has little use in research or graduate class. In any case, a demonstration is made in the corresponding class. On the other hand, this does not prevent a good education in the area, and that allows the student to be prepared to learn and use any type of equipment, regardless of brand, model, and technology onboard.

2.3 Evolution of Topography Teaching in the Face of Scientific, Methodological and Technological Advances: Timeline

This item presents the main developments in Topography and at EPUSP that have provided changes in the teaching of this discipline at the School. These factors of change and evolution are presented in timelines making it possible to establish connections between them and verify and analyze how the teaching of the topic has responded to these transformations.

To enable the presentation and analysis, the timeline was divided into 5 periods, thus generating 5 lines: 1893 to 1920 - foundation and initial years of the Polytechnic School (Figure 1); 1930 to 1950 - the foundation of USP and years of chairs / full professors regime (Figure 2); 1960s and 1970s - University Reform (Figure 3); 1980s and 1990s - the beginning of the widespread use of computers (Figure 4); and 21st Century

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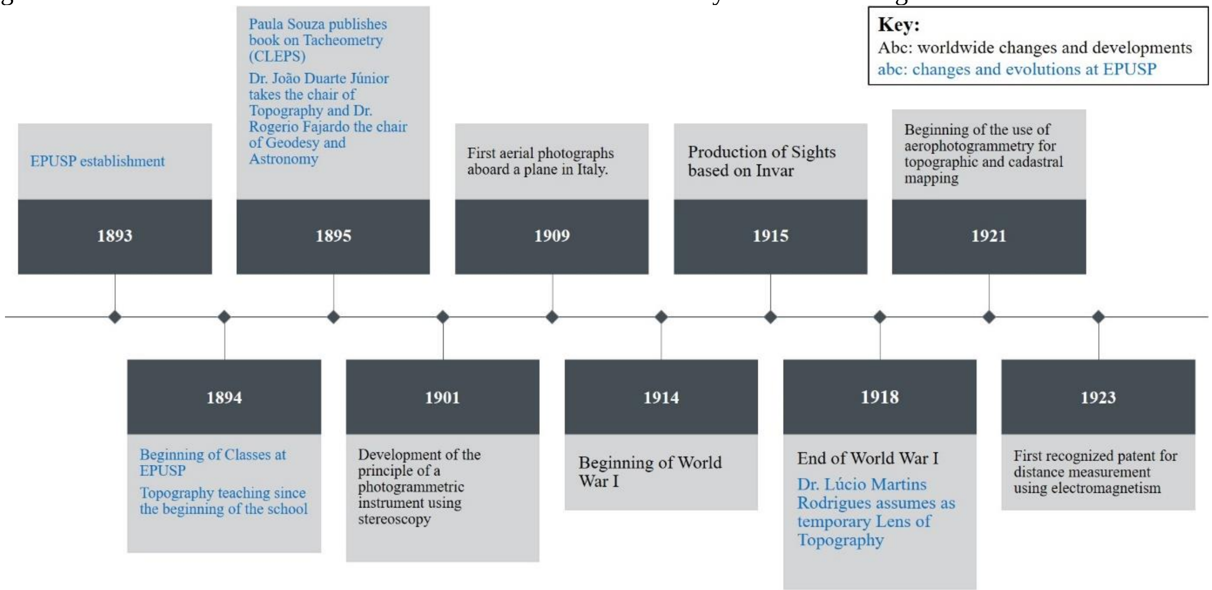
- period of high speed in technological innovations and the appearance of the term Geomatics (Figure 5).

The following presents and briefly comments on each of these times and timelines associated with the figures. The information presented in blue is related to historical landmarks related to the EPUSP, while the information presented in black occurred worldwide.

Figure 1 represents the end of the 19th century and the beginning of the 20th century, a period of great scientific evolution in the field of theories, concepts, and experimentation that enabled technological innovations and advances in the future. An example of this is the aerial photographs, which were previously acquired aboard balloons, and so, the advent of aviation in the early twentieth century was important for the development of aerophotogrammetry (NOVO, 2010).

Figure 1 - Timeline of the Main Historical Milestones of Land Survey and its Teaching at the EPUSP of 1893 – 1930.



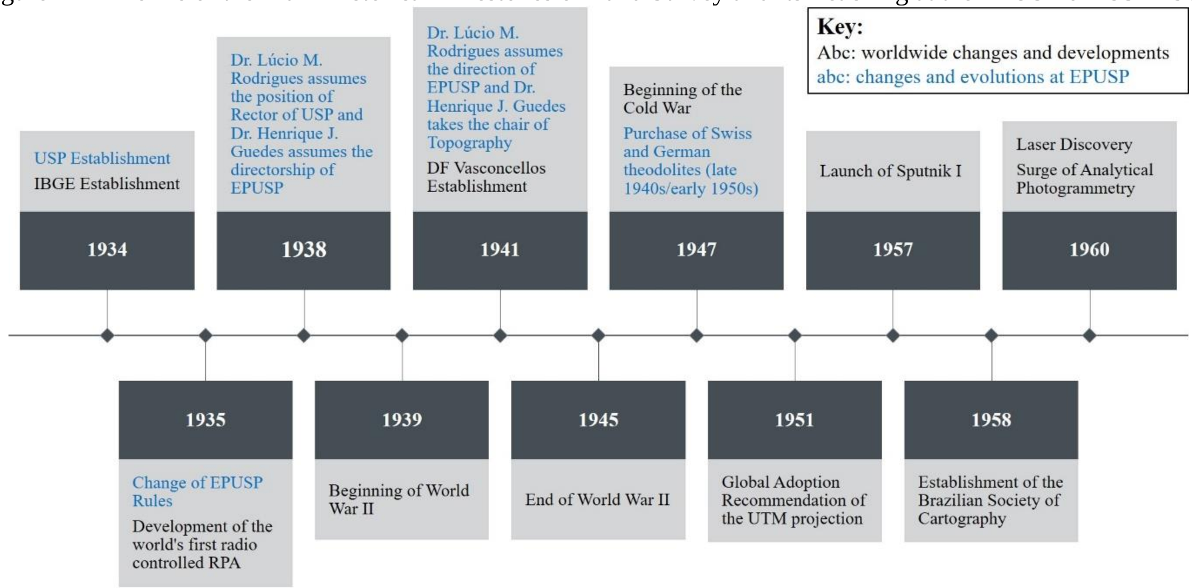
Source: Authors (2020).

The expansion of knowledge about REM and its possible applications, the development of invar - a metallic alloy based on Nickel and Iron - that would guarantee better precision in measurements due to its low thermal expansion coefficient (GRUNER, 1977; WASSERMANN, 1991; WOLF, 2002). This period also saw the First World War, which was less technological than the Second, but where advances in science and technology took place.

At EPUSP, this was a period that preceded the foundation of USP and a period when Prof. Rodrigues, as mentioned joined the teaching staff of the School, coming, in the 1920s, to promote changes in the teaching of Land Survey and the inclusion of new contents.

Related to Figure 2 (1931-1960), at the end of the 1930s World War II began, which brought advances in the field of Surveying, Geodesy, Cartography, and Aerophotogrammetry. During this period, the instruments became more accurate, lighter, and portable, with easier installation and use processes, allowing faster surveys. Spatial knowledge was one of the decisive factors in World War II, and all the scientific, methodological, and technological development of the period was important for the development of the analytical production of spatial knowledge, i.e., mechanisms were created that allowed the realization of processes and computations through these instruments (CLARKE; CLOUD, 2000; HARTCUP, 2000).

Figure 2 - Timeline of the Main Historical Milestones of Land Survey and its Teaching at the EPUSP of 1931-1960.



Source: Authors (2020).

In 1930 an aero photogrammetric map was produced in São Paulo city, in the scale 1:1.000, a world pioneer in this category, produced by SARA Brazil Company. The teaching of this discipline was introduced at EP in the 60's year.

The surveying instruments of that time, mainly theodolites made in Switzerland and Germany, were acquired by EPUSP in the 1950s. However, they were purchased in small quantities and Keuffel & Esser theodolite was kept as the equipment most used in classes and fieldwork.

The amount of equipment for use by the students assumed groups of up to 5 students, in classes of up to 50 students, generating 10 groups. Later, the groups were increased to 60 students and 12 pieces of equipment of each kind were acquired.

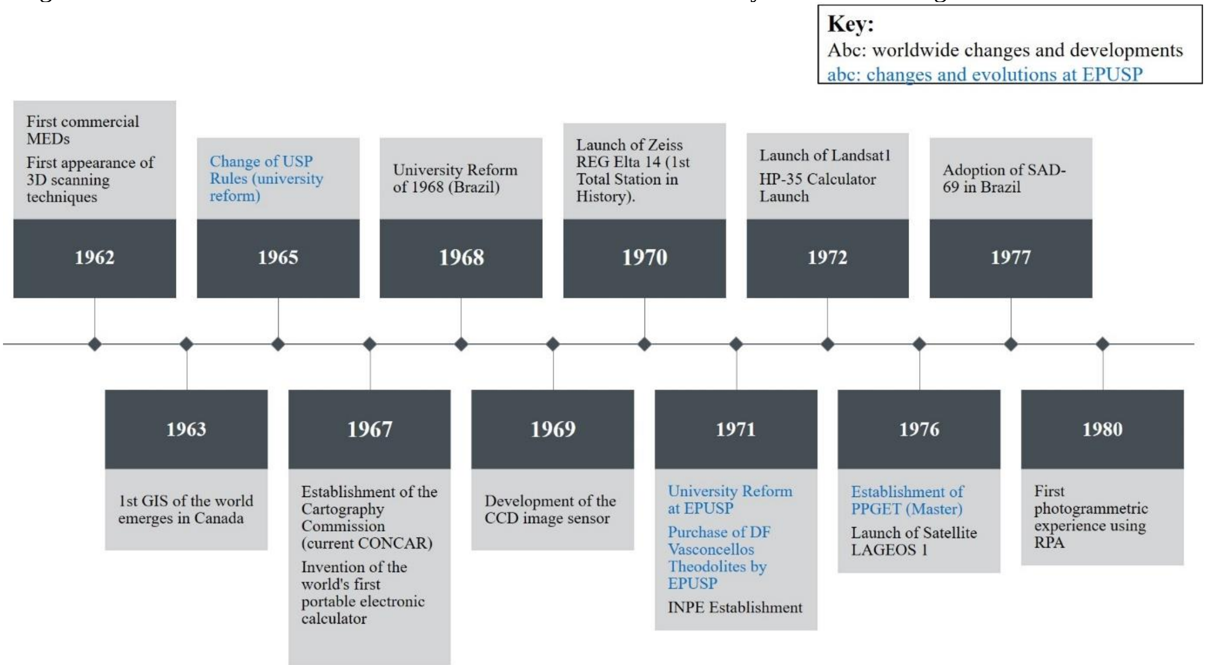
Another field developed during World War II was that of cartographic projections. In the post-war period, given the need and tendency to standardize information in various areas of science, in 1951 the recommendation of the global use of UTM Projection was adopted. The first use of UTM in Brazil was in the mapping and production of the topographic charts in 1:50,000 of the IBGE, from 1962 (flight of the American Air Force - USAF, in a collaboration agreement with Brazil). At EPUSP the introduction of this subject in classes took place in the late 1980s (CINTRA, 1986).

The end of the 1940's and the 1950's were marked by the beginning of Analytical Photogrammetry and Remote Sensing, the laser, the development of electronics and information technology begins to gain strength (MCDOUGALL, 1985).

Moving on to the analysis of the third timeline (Figure 3), it can be highlighted that the advances in Land Survey and related sciences are gradually appearing in the records of the content of the area disciplines at EPUSP. Due to the unfeasibility and even impossibility of access to some technologies (e.g., aerophotogrammetry), these contents were often treated only in a theoretical, conceptual, and demonstrative way. However, in this moment of history, the speed of propagation of new ideas, concepts, and methodologies was not the same as it is today, and in Brazil there was a tendency of delay in the arrival of information and technologies. An example is the time it took for the diffusion and use of UTM projection in Brazil, as well as its teaching.

In the 1960s and 1970s, electronic equipment and computer resources began to be developed and later commercialized that would substantially impact the area of Topography and related sciences, such as the first commercial launches of instruments such as MED, electronic theodolites in the early 1960s and total stations in 1970. There is also the beginning of the development of GNSS, the emergence of the first 3D scanning techniques in 1962, the development of the CCD (charge-coupled device) imaging sensor in 1969, the first electronic calculators during the 1960s, the emergence of GIS in 1963 and the first experiments using RPA in photogrammetry in 1980 (RÜEGER, 1990; WOLF, 2002; MONICO, 2008; SCHERER; LERMA, 2009).

Figure 3 - Timeline of the Main Historical Milestones of Land Survey and its Teaching at EPUSP 1961-1980.



Source: Authors (2020).

In Brazil, it was during the military government that the 1968 University Reform took place, which among other measures ended the *chair system* and instituted the teaching career and departmental system in Brazilian universities, something that, in the long run, was quite salutary. At USP, this change was approved in 1965 and at EPUSP it was implemented in the early 1970s. This change had an impact on Land Survey subjects that started to be taught in 2 semesters, and no longer in 2 years, substantially reducing the teaching workload.

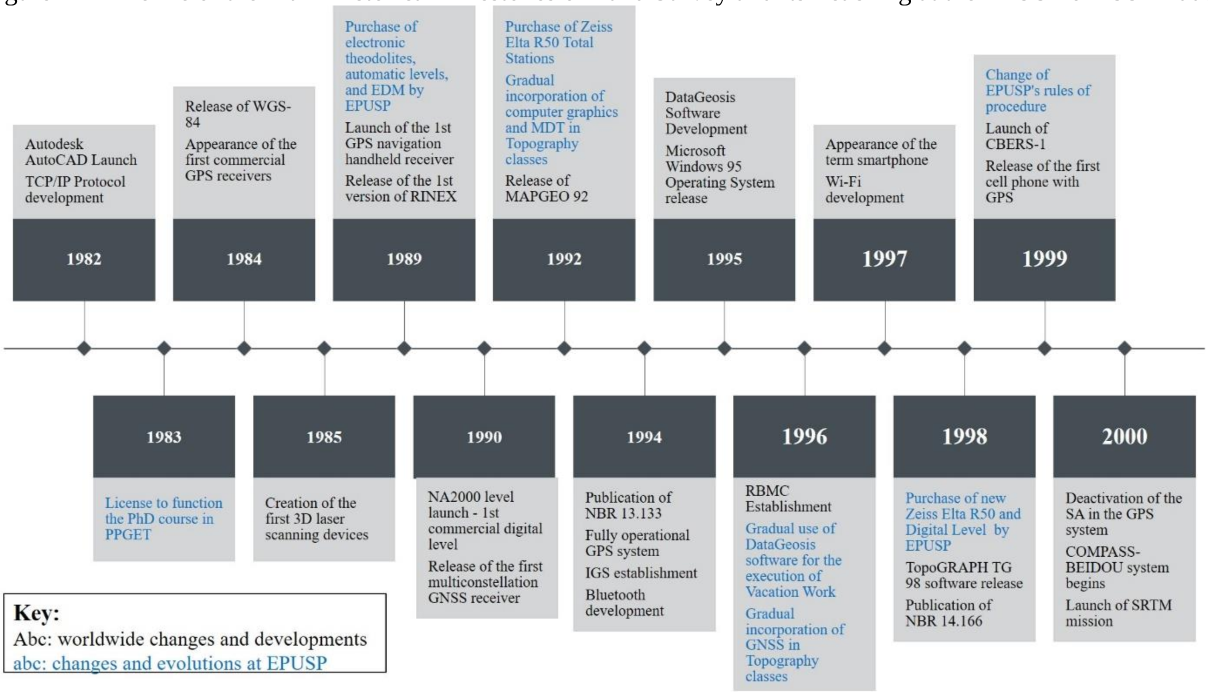
In 1977 SAD-69 was adopted as Brazil's official geodetic reference system. In that same decade, there are records in the program contents of the discipline of the local terrestrial reference systems approach. The SAD-69 and Córrego Alegre (CA) systems were approached briefly in a class and became more developed from the end of the 1980's along with the introduction of the subject in the graduate course.

However, as far as instruments are concerned, the use of calculator machines, for example, is beginning to appear in the disciplines of Land Survey in the third quarter of the 20th Century. It can be said that the EPUSP made it easier for students to use FACIT calculator machines and other mechanical calculators that, from the 1970s on, began to be replaced by electronic calculators. Little by little this facilitation became unnecessary, as the students began to have their own.

Electronic instruments such as total station and electronic theodolites were beginning to be developed in the 1970s, they were very expensive, and their mass production and use came decades later. In the 1970s EPUSP acquired DF Vasconcellos analogical theodolites for use in classes and fieldworkfield work. This acquisition occurred due to the lower cost of these instruments because it was manufactured in the country, was not added to the import tax and the easier maintenance of the equipment; and the factory developed instruments in partnership with USP.

Moving on to the analysis of timeline 4 (1981-2000) (Figure 4), it can be said that in the 1980s research in Surveying and Geodesy began to gain strength at EPUSP with the authorization for the operation of the Doctorate course of the Graduate Program in Transportation Engineering (PPGET) in 1983. The production in Land Survey and related sciences at the postgraduate level through PPGET and the Laboratory of Topography and Geodesy (LTG) enabled the development of research in several fields and themes of the area, which were reflected in the graduation.

Figure 4 - Timeline of the Main Historical Milestones of Land Survey and its Teaching at the EPUSP of 1981-2000.



Source: Authors (2020).

This was also a period of great development of applied software. CAD and specific surveying software allowed to optimize processes, and the time spent on computations (office work and data processing). In the teaching of Land Survey at EPUSP, CAD initially appeared from the 1990s, when it, together with personal computing and computer graphics, became more accessible helping the land surveying and mapping design (CINTRA, 1993). At the end of the 1990s, with the acquisition of total stations by EPUSP, it was possible to start using specific surveying programs (DataGeosis) for the transfer and processing of data from Summer Work surveys.

Some Brazilian standards for the area of Surveying and related sciences, such as NBR 13.133 and NBR 14.166, were developed with the participation of professors from PTR/EPUSP. Many of the meetings for discussion and development of the norms took place on the department's premises.

Digital Cartography, Geoprocessing, Cartographic Bases, Geodesic Reference Systems are subjects that began to be treated at the end of the 90s, even with the decrease in workload (in 1999) with the change in the EPUSP regiment and the reformulation of the disciplines that were named Spatial Information I and II, as said before.

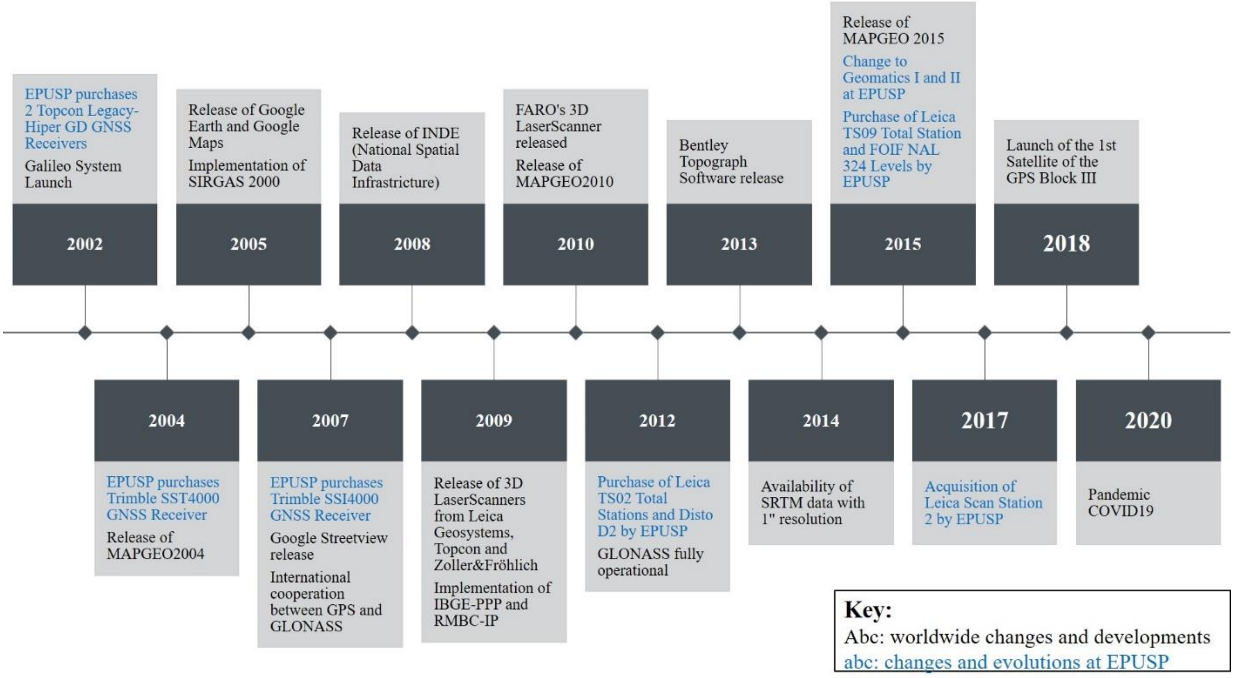
In the area of instruments, the first electronic surveying equipment such as MED and electronic theodolite were acquired in this period. Total stations Zeiss Elta R50 for use in classes and fieldwork were acquired in two moments: the first in the early 1990s in exchange for bags of coffee with Eastern European countries and in 1998 with funds from the Armando Alvares Penteado Foundation (FAAP), due to the donation of the property of the Count Alvares Penteado, whose income must be used in undergraduate laboratories, as a binding clause.

The theoretical and conceptual approach of this instrument (Total Station) had already been performed before its acquisition, when Professor Carlos Rodrigues Ladeira did great research on the subject, with an internal publication at the end of the 1970s; which besides allowing the consolidation of the knowledge developed in the practice of the use of the instrument, was also allied to the need imposed by the reduction of workload since the total station allows the optimization of the time spent for the survey in the field.

The GPS became operational in the year 2000 when the selective availability was shut down, moving towards the popularization and consolidation of the civil use of GNSS. At EPUSP, satellite positioning was initially approached at the graduate level at the beginning of the 1990s, enabling its approach at the undergraduate level at the end of that decade, with many contributions from the professors hired at the beginning of the decade.

Concerning timeline n. 5 (2000-2020) (Figure 5), it can be started by saying that the 21st Century is marked by the fast pace of innovations and technological advances where the obsolescence of computer instruments and resources becomes increasingly faster and with a high degree of digitalization of the world technology. This scenario is full of challenges and possibilities for the area of Geomatics and its teaching (SLADE, 2006; LI; SHEN; WANG, 2018; SILVA, 2020).

Figure 5 - Timeline of the Main Historical Milestones of Land Survey and its Teaching at the EPUSP of 2000-2020.



Source: Authors (2020)

As occurred and became clear in other periods, also in this one, in the teaching of Topography methodological, scientific, and technological advances were inserted in the content of the disciplines in the area, such as the use of more modern Total Stations, with laser plumbing and with better accuracy. Subjects that in 2015 were changed to Geomatics I and II, thus there was a reorganization and restructuring of the teaching of the area by LTG and, in parallel with the Laboratory of Geoprocessing (LGP). Instruments with greater technological development were acquired for massive use in classes and research as the Total Leica TS02 Station, the electronic D2 trains, the FOIF automatic levels, and GPS navigation receivers. Other types of equipment were acquired mainly for use at the graduate level as the Total Leica TS09 station, GNSS geodetic receivers, and the Laser Scanner Leica Scan Station 2.

At the end of 2019, on November 11, an agreement was signed between the EPUSP and Trimble Europe B. V. which provides for the donation of instruments from this manufacturer (DOSP, 2019). This agreement will allow the updating and use of various instruments in Geomatics at the graduate and postgraduate degrees.

3 POSTGRADUATE CONTRIBUTIONS TO THE TEACHING OF TOPOGRAPHY

The Post-Graduation in Transportation Engineering was officially recognized at the master’s level in 1976 and Ph.D. level in 1983 (LOSCHIAVO DOS SANTOS, 1985). In the 1980's there was no official line of research in Topography or related areas, however, first through the orientation of Prof. Felippe Augusto Aranha Domingues, the research was initiated.

The creation of the research line officially with this title in spatial information occurs at the beginning 1990s. This work will focus on the current line of Cartography, Geodesy, and Topography. For this work we have consulted the Lattes Curriculum of six professors who have or had links with LTG (Topography and Geodesy Laboratory) and PPGET (Transportation Engineering Graduate Program): Jorge Pimentel Cintra (started in 1986); Nicola Paciléo Netto (1991 until 2009); Denizar Blitzkow (started in 1990); Edvaldo Simões da Fonseca Junior (started in 2004); Ana Paula Camargo Larocca (2009 until 2013); and Flavio Guilherme Vaz de Almeida Filho (started in 2014).

Within LTG, when looking at the Lattes curriculum of the six teachers who integrated and are part of LTG, from 1990 to 2020, there is an extensive production volume that contributed directly and indirectly to the teaching of Geomatics. This extensive volume includes research projects, publications in journals and proceedings of scientific events, book chapters, technical productions, elaboration of norms and didactic material, as well as the guidelines for Master's, Doctorate, and Scientific Initiation (CI).

Direct contributions are considered to research and publications that have teaching as a central theme, whether in the development of some tool, in the discussion of methodologies, or in any other type of approach that discusses the teaching of the area. As for indirect contributions, publications, and research that constitute a metric and a signal of contribution to the development and evolution of scientific knowledge and technological innovations that present potential for application and contribution to the development of teaching at undergraduate and graduate levels are considered.

Looking at the themes in which research and publications have been carried out over time (Table 1), it is possible to understand how LTG at the postgraduate degree has developed research and publications that have been and continue to be aligned with scientific, methodological, and technological development and evolution.

Two examples of this are the research conducted on GNSS themes, geodesic networks and reference geodesic systems that contributed to the development and adoption of SIRGAS-2000 as the official geodetic reference system of the Brazilian Geodetic System (SGB) and the research in Physical Geodesy that contributed to the development of the Brazilian geoidal model (MAPGEO) linked to the SGB. These themes, as well as the adoption of SIRGAS and the problems of altitude in Geodesy are themes developed within the Post-Graduation framework and rapidly incorporated and worked on within the undergraduate framework.

Observing the development and incidence of research and production themes over time, one can see how they follow the scientific, methodological, and technological evolutions, making it possible to understand how the *stricto sensu* post-graduation environment, where strict scientific research is developed and aligned with the conjuncture and needs at regional, national and global levels, enables the Higher Education Institution (HEI) and its teaching to be following the evolution.

The graduate course is not only a space for training researchers and conducting research, but also a space for training teachers to work in Higher Education. The Law of Directives and Basis (LDB) of Brazilian Education presents in its article 66 that "the preparation for the exercise of higher education will be done at the graduation level, especially in masters and doctorate programs" (BRASIL, 1996).

Through the analysis of the Lattes Curriculum of the PPGET advisors linked to LTG was seeking information on the completed masters and Ph.D. orientations. With access to the Lattes Curriculum of PPGET Masters and PhDs with LTG faculty advisors, a quantitative check was made of information such as the number of former students who had some teaching experience, as well as checking at what level of teaching and type of HEIs they worked or are working in (Table 2).

Table 1 - Scientific production by themes over time (5-year intervals), based on the Lattes curriculum of PPGET professors - LTG.

Themes	**2020-2016**	**2015-2011**	**2010-2006**	**2005-2001**	**2000-1996**	**1995-1991**	**1990-1986**	**1985-1981**	**Sum**
Teaching	2	12	12	7	14	5	13	0	65
Angle / distance / leveling surveying instruments	0	7	2	1	8	16	0	0	34
Global Navigation Satellite System (GNSS)	8	23	19	21	38	25	0	0	134
Geodetic Reference System	3	5	3	21	15	9	2	0	58
Geodetic Network	0	1	0	15	13	8	2	0	39
Survey Methods and Techniques	3	8	5	7	13	6	0	0	42
Measuring/Calibration Base for Instruments	1	2	3	5	9	10	0	0	30

(To be continue)

(Conclusion)

Themes	2020-2016	2015-2011	2010-2006	2005-2001	2000-1996	1995-1991	1990-1986	1985-1981	Sum
DTM	1	0	5	8	8	7	3	2	34
Geomatics Applications in Engineering	12	22	16	18	18	8	1	0	95
Remote Sensing	2	9	6	9	13	4	0	0	43
Computer Science in Land Survey (CAD / Data Processing)	0	13	8	9	17	6	8	0	61
Physical Geodesy	11	18	14	24	12	7	6	0	92
GIS	0	4	0	5	11	3	0	0	23
Aerophotogrammetry	2	1	1	5	3	2	0	0	14
RPA / UAVs	3	0	0	0	0	0	0	0	3
Laser Scanner	9	2	3	0	1	0	0	0	15
Evaluation of Instruments / Methodologies	7	9	5	17	17	7	2	0	64
Computational Tool Development	2	4	7	7	8	0	2	1	31
Digital Cartography / Cartographic Bases	4	4	4	20	21	11	0	0	64
Quality Control / Map Accuracy / Data and Surveys	4	8	4	14	3	4	0	0	37
Literature Review	3	6	1	8	3	2	0	0	23
Standards (Development / Analysis)	0	0	0	6	1	1	0	0	8

Source: The authors (2020).

Eighty-eight graduates from the masters and Ph.D. levels were studied, and of these, 56 have some record of teaching experience in the Lattes curriculum, corresponding to approximately 64% of those surveyed. Among the other 32, fifteen had no record found in the Lattes platform and seventeen have no record of experience in the teaching career in their curriculum. In fact, many postgraduates worked and work in the private initiative, in public agencies, city halls, and others, acting in spatial information. It is worth mentioning that the sum of the totals in Table 2 is not equivalent to the total number of teachers trained in LTG in PPGET, because a teacher may be in more than one row of the table.

Table 2 - Masters and Doctors graduated in LTG - PPGET having teaching experience, based on the Lattes curriculum of PPGET professors - LTG.

Experience	Master in PPGET (only)	Ph.D. in PPGET (only)	Master and Ph.D. in PPGET (only)	Total
Taught Private HEIs	10	2	10	22
Teaches Private HEIs	3	2	3	8
Taught State HEIs	0	3	3	6
Teaches State HEIs	9	15	10	34
Taught Technical School	3	1	1	5
Teaches at Technical School	2	0	0	2

Source: The authors (2020).

Among those who have at least some experience in the teaching career, many have followed IES (Higher Education Institutes) of relevance in Brazilian Higher Education and have developed as researchers and teachers in these institutions, and for the most part the beginning of the construction of their teaching professionalism took place in the space of graduate studies, being this an important space for the initial development of teaching in Higher Education. Among the professors who graduated in master's and Ph.D., there are teachers from IME, UFPR, UNICAMP, UFMG, UNESP, USP at São Carlos, UERJ, UFRJ UFU, UFV, UFSM, UEM, UNB, UFGO, UFBA, FEI, among others.

4 PERSPECTIVES AND CHALLENGES FOR TEACHING GEOMATICS

The next years and decades of the XXI Century suggest a continuity in the process of technological evolution and innovation at accelerated rates, the same for society, with changes in interaction processes, which are increasingly mediated by technologies. Education, including the area of Spatial Information, is seen within this process, impacted by evolutions in technology and by behavioral and social changes.

The 21st Century is also marked by interdisciplinarity and multitasking. More and more demands are made on these qualities of professionals, in addition to enterprising and innovative characteristics. Among these characteristics, one cannot lose sight of the theoretical-conceptual training of engineers in the face of a world increasingly focused on practice and at an ever-increasing pace of technological innovation. Therefore, a constant discussion about the structure of Geomatics teaching, by teachers and researchers in the area tends to be positive to advance the quality of training of new engineers (SILVA, 2016; SILVA, 2020).

The forecast is for increasing knowledge and a constant teaching time (number of classes), which requires a choice of contents, to avoid superficiality. And, chosen the subject, to penetrate with certain depth to transmit ways of thinking and reasoning in this area, with examples and concrete cases of engineering; few, but that teach to think. The teaching and learning of essential concepts, possibly linked to the geometrization of space (angles, distances, coordinates, referential) must be guaranteed; errors and precision associated to measurements, quality control, graphic expressions (plans, charts) and their reading. And choosing, at each time as an illustration, some equipment, and its principles. For example, GNSS, photogrammetric surveys with drone. It is also possible to extend the training through modules and optional discipline within the course of civil engineering. One can also think that, in professional practice, the civil engineer will necessarily rely on the collaboration of specialists: surveyors and cartographers engineers.

In the point of view of learning, it is necessary to discuss how ICT (Information and Communication Technology) and the EdTechs (educational technologies) can be allied tools in Geomatics teaching. It is necessary to think about the insertion, adaptation, and use of smartphones, video, and distance learning platforms, animations and computer simulators, the gamification of Education and virtual reality and augmented reality devices, among other advances and technological tools to enhance teaching and learning (KONECNY, 2002; BEDNARCZYK, 2017). The EdTechs can be used, for example, in the absence of instruments of the area, allowing the visualization by the student of the use of this equipment helping him to consolidate and mean the concepts developed, especially in the case of few practical exercises. This already occurs for a certain time, being used in class demonstration videos of use and practical application of some equipment, as the laser scanner, which is currently a subject worked in this way.

There are also the Active Learning Methodologies, which as well as the educational technologies can also be a tool to enhance the teaching-learning process and the meaning and practical visualization of the concepts worked on (ELMÔR FILHO et al., 2019). Both the Active Methodologies and the EdTechs can also be allied in facing the reduction of workload available for the teaching of Geomatics in Engineering courses.

Facing the COVID-19 Pandemic and the need for distance and social isolation imposed by it, many HEIs, among them the EPUSP, began to carry out teaching mediated by technologies, performed in a synchronous and/or asynchronous remote way, becoming known as Emergency Remote Teaching (ERT). The solutions in the HEIs were diverse, and in many cases chosen and improved with the academic semester in progress. The ERT accelerated the use of a possibility that was latent in Brazilian HEIs and the world, which is the technological mediation of teaching and remote teaching and the use of its tools in face-to-face teaching.

The emergency use of technological mediation in remote teaching has exposed the potential and weaknesses of the use of these tools, showing that the effectiveness and success of remote teaching depends on a lot of planning and bringing many doubts, perspectives, challenges, and questions, which should be thought and discussed for the area of Geomatics Teaching: how to develop the remote teaching of Geomatics effectively? How to assess effective learning? What are the models, techniques and tools for remote teaching that can enhance the teaching of Geomatics? Are teachers in the area prepared to use these methodologies and technologies? Would it be possible to teach a Geomatics course or subject totally remote? Would a hybrid teaching model be the most appropriate for the area? How will the practical classes and topographic and geodesic surveys in the field be carried out? These, among other questions, are posed to be thought and discussed by teachers and researchers in the field of Geomatics.

5 CONCLUSIONS

The Teaching of Topography and related sciences (currently Geomatics) at EPUSP went through many stages and moments, being impacted by changes and evolutions of different sorts. The changes and evolutions were absorbed in several ways, initially depending more on the personal action of the *chair lenses*, later the movement, and unity of the departments and graduate programs.

The history of more than a century of surveying teaching at EPUSP shows that teaching must be tuned to scientific, methodological, and technological developments and innovations that are consolidated in the professional exercise of the area. The scientific and methodological evolutions, whenever possible, were quickly absorbed and incorporated in the teaching of Geomatics at EPUSP, when it was not involved in any way in the development processes of the area.

As for instrumental developments, the trend is that instruments with technological innovations are of high cost and little economic viability to be acquired on a large scale, making it impossible to use them in undergraduate studies; however, EPUSP's experience has shown that this is possible and that, in extreme cases, they point to alternative ways of being worked on conceptually and research results are shown during graduate classes. In other words, the unfeasibility of access to modern resources and instruments with high technology onboard is not and cannot be a barrier to the development of a good Geomatics education.

For all that was pointed out, the training must be strongly supported and based on the concepts of Geomatics, which will enable the student to develop skills and competencies for professional exercise regardless of the level of technology to which they have access, thus being prepared to adapt to scientific, methodological, and technological developments.

Finally, scientific, methodological, and technological advances must be seen and worked on to be integrated into the programmatic content of the disciplines in the area, always taking into account the need to emphasize concepts and understand that technology is a tool (a means) and should not be seen as an end.

Authors Contribution

Author 1 (Jhonnes Alberto Vaz) did: conceptualization, data curatorship, research, visualization, and writing - initial draft. Author 2 (Jorge Pimentel Cintra) carried out: structure of the work, suggestion and selection of periods and historical facts, final review of the text. Author 3 (Flávio Guilherme Vaz de Almeida Filho) carried out: support in the design of the work structure, contribution in the construction of the current and future scenario, version, and final review of the text.

Conflicts of Interest

The authors declare that there is no conflict of interest.

References

AMARAL, André Henrique Freitas do. PET Entrevista Fábio Cozman. **Revista Autômato**. Edição Especial – A EC3, p. 6-8, 2014. Disponível em: <https://sites.usp.br/petmecatronica/wp-content/uploads/sites/690/2018/04/Automato_10-compressed.pdf> Acesso em: 24 jul. 2020.

BALBO, José Tadeu. A Nova Estrutura Curricular para o Ensino de Engenharia Civil na Poli-USP. **Revista Concreto & Construções**. v. 44, n. 85, p. 65-69, 2017.

BEDNARCZYK, Michal. The Use of Augmented Reality in Geomatics. In: ENVIRONMENTAL ENGINEERING 10th INTERNATIONAL CONFERENCE, 2017, Lituânia: 27-28 abr. **Proceedings...** Vilnius Gediminas Technical University, Lituânia, 2017. DOI.: 10.3846/enviro.2017.162

BRAGGIO, Ana Karine. A Gênese da Reforma Universitária Brasileira. **Revista Brasileira de História da Educação**. v. 19, p. 1-26, 2019. DOI.: 10402.51920.19073

BRASIL. **Lei n° 9.394, de 20 de dezembro de 1996**. Que estabelece as diretrizes e bases da educação nacional. Disponível em: <http://bd.camara.gov.br/bd/bitstream/handle/bdcamara/2762/ldb_8.ed.pdf?sequence=1>. Acesso em: 30 maio 2020.

CAMPOS, Cristina. **Ferrovias e saneamento em São Paulo. O Engenheiro Antonio Francisco de Paula Souza e a construção de rede de infra-estrutura territorial e urbana paulista, 1870-1893**. 2007. 411 p. Tese (Doutorado – Área de Concentração: História e Fundamentos da Arquitetura e Urbanismo) – Faculdade de Arquitetura e Urbanismo, Universidade de São Paulo, São Paulo, 2007.

CAMPOS, Cristina; GITAHY, Maria Lucia Caira. O percurso de um engenheiro politécnico paulista. Antonio Francisco de Paula Souza e a configuração das redes de infra-estrutura em São Paulo, nas últimas décadas do Século XIX. **Pós**. v. 16, n. 26, p. 184-200, 2009. DOI.: 10116.06231.72762.02618.42 00

CINTRA, Jorge Pimentel. O ensino da Topografia nas Escolas de Engenharia. **Revista de Ensino de Engenharia**. v. 5, n. 1, p. 91-101, 1986.

CINTRA, Jorge Pimentel. **Automação da Topografia: Do Campo ao Projeto**. 1993. Tese (Livre Docência) - Escola Politécnica, Universidade de São Paulo, São Paulo, 1993.

CINTRA, Jorge Pimentel. **PTR 2201 – Informações Espaciais I: Notas de Aula**. São Paulo: EPUSP, 2012.

CLARKE, K. C.; CLOUD, J. G. On the origins of Analytical Cartography. **Cartography and Geographic Information Science**. v. 27, n. 3, p. 195-204, 2000. DOI.: 10155.91523.04000.78354.7821

DOSP, Diário Oficial do Estado de São Paulo. **Diário Oficial do Estado de São Paulo de 11 de dezembro de 2019, Executivo Caderno 1**. São Paulo: Imprensa Oficial, p. 78, 2019.

ELMÔR FILHO, Gabriel et al. **Uma Nova Sala de Aula é Possível: aprendizagem ativa na Educação em Engenharia**. Rio de Janeiro: LTC, 2019

GOLDEMBERG, José. **USP 80 anos**. São Paulo: EDUSP, 2015.

GRUNER, Heinz. Photogrammetry: 1776 – 1976. **Photogrammetric Engineering and Remote Sensing**. v. 43, n.5, p. 569-574, 1977.

HARTCUP, Guy. **The Effect of Science on the Second World War**. London: Macmillan Press LTD, 2000.

IHDE, Johannes; REINHOLD, Andreas. Friedrich Robert Helmert, founder of modern geodesy, on the occasion of the centenary of his death. **History of Geo and Space Sciences**. v. 8, p. 79-95, 2017. DOI.: 10.5194/hgss-8-79-2017

KONECNY, Gottfried. Recent Global Changes in Geomatics Education. In: ISPRS COMMISSION VI SYMPOSIUM 2002: NEW APPROACHES FOR EDUCATION AND COMMUNICATION, XXXIV, São José dos Campos, SP, 2002. **ISPRS Archives**. São José dos Campos, SP: INPE, 16-18 set. 2002. Disponível em: <https://www.isprs.org/proceedings/XXXIV/part6/papers/019.pdf>. Acesso em: 10 jun. 2020.

LEITE, Werlayne Stuart Soares; RIBEIRO, Carlos Augusto do Nascimento. A Inclusão das TICs na Educação Brasileira: Problemas e Desafios. **Magis, Revista Internacional de Investigación em Educación**. v. 5, n. 10, p. 173-187. Bogotá: Pontifícia Universidade Javariana, 2012. DOI.: 10.11144/Javeriana.m5-10.idtn

LI, Deren; SHEN, Xin; WANG, Le. Connected Geomatics in the big data era. **International Journal of Digital Earth**. v. 11, n. 2, p. 139-153, 2018. DOI: https://doi.org/10.1080/17538947.2017.1311953

LOSCHIAVO DOS SANTOS, Maria Cecília. **Escola Politécnica da Universidade de São Paulo: 1894 - 1984**. São Paulo: EDUSP, 1985.

MANIERO, Léo; VANDERLINDE, Walpy. **Curso de Topografia**. ed. 3. São Paulo: EPUSP, 1954.

MARTINS, Carlos Benedito. A Reforma Universitária de 1968 e a Abertura para o Ensino Superior Privado no Brasil. **Educação & Sociedade**. v. 30, n. 106, p. 15-35. Centro de Estudos Educação e Sociedade: Campinas, 2009. DOI.: 10159.0S010.17330.20090.00100.002

MCDOUGALL, W. A. Sputnik, the Space Race, and the Cold War. **Bulletin of the Atomic Scientists**. v. 41,

n. 5, p. 20-25, 1985. DOI.: 10108.00096.34021.98511.45596.2

MESQUITA, Paulo Ferraz de. Astronomia Espherica. **Revista Polytechnica**. 1934.

MESQUITA, Paulo Ferraz de. **Análise de niveldiastímetro**. 1959.Universidade de São Paulo, São Paulo, 1959.

MESQUITA, Paulo Ferraz de. **Carta de Paulo Ferraz de Mesquita aos membros da Comissão do livro técnico e didático do MEC acerca da oportunidade da publicação do "Tratado teórico e prático de topografia", de Albano da França Rocha**. São Paulo: 2 dez. 1966. Disponível em: <https://www.docvirt.com/docreader.net/docreader.aspx?bib=AT_Corresp&pasta=AT%20c%201966.12.02&pagfis=12853> Acesso em: 26 jul. 2020.

MESQUITA, Paulo Ferraz de. **Curso Básico de Topografia, Astronomia de Posição e Geodésia**. ed. 2. São Paulo: Dlp. 1969.

MONICO, João Francisco Galera. **Posicionamento pelo GNSS: Descrição, Fundamentos e Aplicações**. ed. 2. São Paulo: Editora Unesp, 2008.

NOVO, Evlyn M. L. de Moraes. **Sensoriamento Remoto: princípios e aplicações**. ed. 4. São Paulo: Blucher, 2010.

PADILHA, Rodrigo Bastos. **Antônio Francisco de Paula Souza: criador da Escola Politécnica de São Paulo, engenheiro, político e educador**. São Paulo: Leopardo Editora, 2010.

RODRIGUES, Lúcio Martins. **Notas de Aula do Curso de Topographia do Dr. Lucio Rodrigues**. São Paulo: EPUSP, 1923.

RÜEGER, Jean M. **Eletronic Distance Measurement: an introduction**. Berlim: Springer-Verlag, 1990.

SANTOS, Paulo Marques dos. O Instituto Astronômico e Geofísico da USP. In: MATSUURA, Oscar T. (organizador). **História da Astronomia no Brasil**. v. 1. Recife: Cepe, 2014.

SCHERER, Michael; LERMA, José Luis. From the conventional Total Station to the Prospective Image Assisted Photogrammetric Scanning Total Station: Comprehensive Review. **Journal of Surveying Engineering**. v. 135, n. 4, p. 173-178, 2009. DOI.: 10106.10733.94532.00913.54173

SILVA, Irineu da. El Futuro de la Educación em Geomática para la Ingeniería Civil. CONCENCIÓN Y FERIA INTERNACIONAL INFORMÁTICA, XVI, 2016, Havana, Cuba. **Anais...** Havana, Cuba: 14-18 mar., 2016.

SILVA, Irineu da. Geomatics Applied to Civil Engineering State of the Art. In: GHOSH, Jayanta Kumar; SILVA, Irineu da. **Applications of Geomatics in Civil Engineering – Select Proceedings of ICGCE 2018**. Singapore: Springer Nature, 2020. DOI.: 10100.79789.81137.0670

SLADE. Giles. **Made to Break: technology and obsolescence in America**. Cambridge: Harvard University Press, 2006.

SOUSA, Gisela Mangabeira de; et al. O uso do SPRING como ferramenta de aprendizagem de Geoprocessamento. JORNADA DE EDUCAÇÃO EM SENSORIAMENTO REMOTO NO ÂMBITO DO MERCOSUL. IV, 2004, São Leopoldo, RS. **Anais...** São José dos Campos, SP: INPE, 11-13 ago., 2004. Disponível em: <http://www3.inpe.br/unidades/cep/atividadescep/jornada/programa/t-8_trab_30.pdf>. Acesso em: 24 jul. 2020.

SOUSA, Marcos Timóteo Rodrigues de; ROSAS, Celbo Antonio Fonseca. O Uso do Teodolito Mecânico no Ensino de Topografia: As formas “artesanais” de coleta de dados frente as novas tecnologias de precisão. **Ciência Geográfica**. v. 23, n. 1, p. 309-315, 2019.

SOUZA, Antonio Francisco de Paula. **Elementos de Taqueometria: cleps, descrição e uso prático deste instrumento**. São Paulo: [s.n.], 1895.

WASSERMANN, E. F. The Invar Problem. **Journal of Magnetism and Magnetic Materials**. v. 100, n. 1-3, p. 346, 362, 1991. DOI.: 10101.60304.88539.19082.8-X

WOLF, Paul R. Surveying and Mapping: history, current status, and future projections. **Journal of Surveying**

Engineering. v. 128, n. 3, p. 79-107, 2002. DOI.: 10106.10733.94532.00212.8379

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