Application of Problem-Based Learning in a non-face-to-face modality in crisis situations, based on the changes required to promote the associated learning process.

Master in Problem Based Learning on Engineering and Science (MPBL)

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Abstract

With this Thesis, case study type research was developed whose objective was the “Application of Problem-Based Learning in a non-face-to-face modality in crisis situations, based on the changes required to promote the associated learning process.” For this, the impact that the abrupt and disruptive transition to a non-face-to-face learning modality had on students was determined. It was found, as aspects such as technology (computers, mobile devices, tablets, internet), the training of teachers for a virtual work modality and their attitude about change, tools related to computer applications (software); were elements that significantly affected their learning processes, among others. The students' conception about autonomous learning and collaborative learning was also investigated, with which the importance they give to these concepts and their application in a non-presence environment was established. They also asked about study techniques used and learning preferences. All this allowed establishing the requirements associated with the changes in curricular components required to develop non-face-to-face learning. Autonomous and collaborative communication and workspaces were implemented using platforms such as Symbaloo ©, Google Meet ©, Google Drive ©, Moodle ©. With these, it was possible to show how the students did not privilege the specific use of a recommended space if they used platforms better known to them. In general, from the results obtained, it can be concluded that it is possible to develop a theoretical and practical course in a non-face-to-face way, using the PBL methodology. However, the general feeling was that a vacuum was generated due to the impossibility of conducting face-to-face laboratory practices.

Keywords

Problem-Based Learning Online, Emotions, Personal Learning Environments, Connectivism, Learning Styles

1 Introduction

1.1 Context of the Problem

In the initial context of the current pandemic caused by COVID-19, education systems worldwide have been forced to change methodologies related to learning processes. In Colombia, on March 12, 2020, the health emergency declaration was made by Resolution 385 of March 12, 2020, of the Ministries of Health and Social Protection [1]. Presidential Directive No. 02 of March 12, 2020, established guidelines for developing work at home using ICT's [2]. Based on this regulatory framework and under a joint statement from the Ministry of National Education, the State University System-SUE, the Colombian Association of Universities-ASCUN, and the Network of Technical, Technological and University Institutions-REDTTU [3], the National University of Colombia suspended face-to-face classes as of March 16, 2020, through statement 09 of March 15, 2020, of the Rectory. They established other provisions to ensure the health and integrity of the University's academic and administrative community. These include the use of virtual platforms and electronic media for all educational activities [4]

After more than a year of pandemic, UNICEF reported that "more than 168 million children in the world, have been completely closed for almost a year, due to the confinements imposed by COVID-19. Furthermore, around 214 million children in the world (one in seven) have lost more than three-quarters of their face-to-face education " **[5].**

The National University of Colombia (UNC) established a return protocol for the resumption of face-to-face activities following the provisions of the National Government, the Mayor of Bogota, and the guidelines set in UNC Rectory Resolution 338 of 2020. [6]

Figure 1 illustrates the four (4) phases of resumption of activities established for the first semester of 2020:

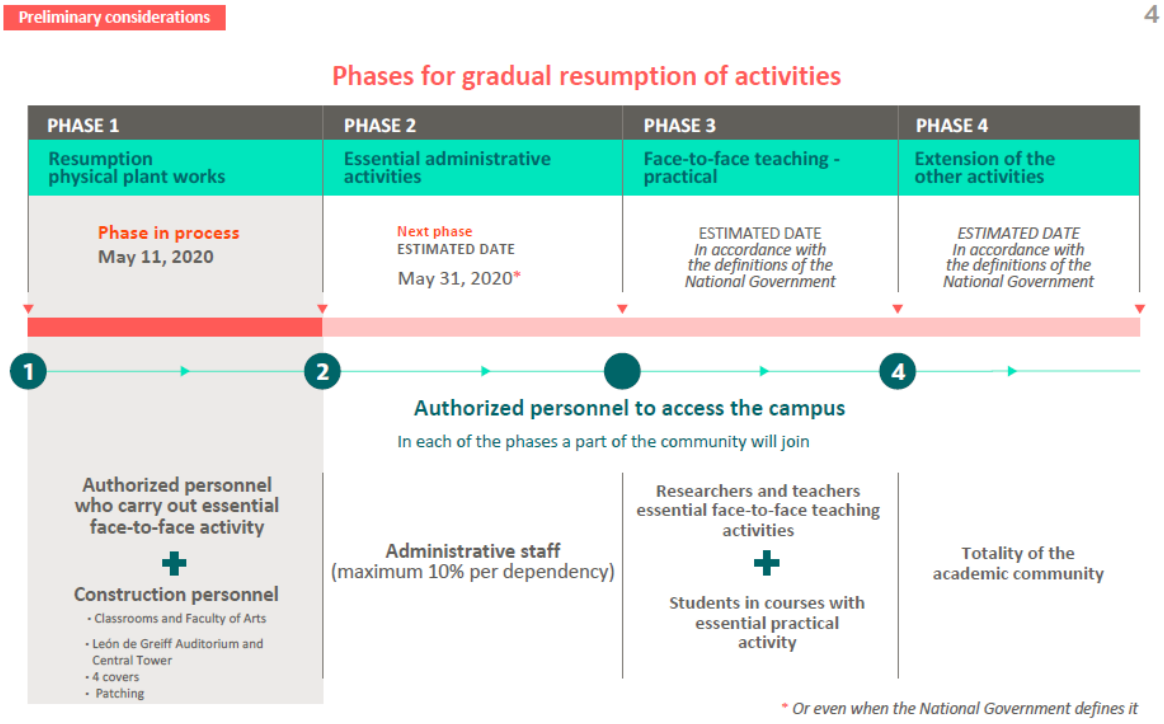

Figure 1 Phases for Gradual Resumption of Activities. National University of Colombia1 (Taken and translated from GENERAL GUIDE – Universidad Nacional de Colombia)

In a statement of May 19, 2020, the National Government announced that it would keep virtual classes and work at home in universities until July 30, 2020, by COVID-19 [7].

Until the time of development of this thesis (academic period 2020-02), following government guidelines, in particular Resolution 1462 of August 25, 2020, of the Ministry of Health and Social Protection, which resolved, among other points, to extend the health emergency until November 30, 2020, it was established to continue with the education processes, not face-to-face. Due to the above, it was not possible to develop the phases for gradual resumption of activities. (Figure 1)

It should be noted that the reports of Johns Hopkins University for Colombia show that Colombia presented its first peak around August 16, 2020, at the beginning of the second academic term of this year. Figure 2 shows the behavior of infections for this date, and Figure 3 that of deaths [8].

Nowadays, based on the epidemiological evolution of the pandemic in Colombia, the Ministry of Health and Social Protection has extended the health emergency, for which it issued Resolutions 844, 1462, 2230 of 2020; such as Resolutions 738 and 1315 of 2021 [9]. The latter extended the health emergency until November 30, 2021.

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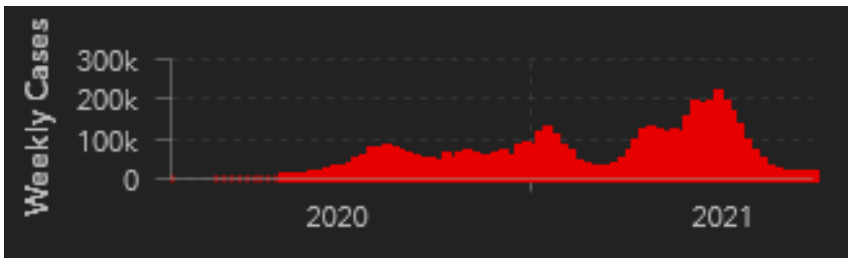


Figure 2 Covid 19 - Cumulative cases and deaths for Colombia until October 2021 (Taken from: [8])

Figure 3 Weekly doses of vaccines administrated until September 2021 (Taken from: [8])

It is important to mention that, to date, the National University of Colombia has continued with the non-face-to-face learning modality during the second academic semester of 2021, combined with a gradual and alternate return for administrative and teaching activities. Also, in compliance with the established biosafety measures, the development of associated activities to research projects or learning processes that require experimentation in laboratories and spaces set up for this purpose.

Concerning the mental condition of university students in the face of the isolation process and its impact on learning activities, different studies show results in which problems such as anxiety, depression, loss of sleep quality, suicide attempts, among others, are reported [10] [11] [12] [13] [14] [15] [16]. Furthermore, studies published during the second semester of 2020 [17] [18], and in 2021 [19] [20], related to the impact of Covid 19 on university students, show how after more than six months and almost a year of pandemic, the situation is not better than previously reported.

For the year 2021, the situation is similar. A study carried out at the University of Guanajuato (MX) shows that 16.28% of the students showed moderate to severe depressive symptoms, 67.11% showed moderate to severe anxiety symptoms, and 63.79% showed levels of stress between mild and severe [21]. A survey carried out by UNICEF to 8,444 adolescents and young people between the ages of 13 and 29 in nine countries and territories of the Latin American and Caribbean region, related to "The impact of COVID-19 on the mental health of adolescents and young people". It showed that 27% show anxiety symptoms, 15% symptoms of depression, with the main cause related to the economic situation; 46% said they felt less motivated to carry out activities of their choice, and 36% habitual activities. On the other hand, 73% felt the need to request help related to their physical and mental well-being, although only 40% resorted to it [22].

On the other hand, the Observatory INSTITUTE FOR THE FUTURE OF EDUCATION, of the Tecnológico de Monterrey (MX), reports the impact of Covid-19 on the mental health of graduate students. Thus, "according to a report by the National Academies of Sciences, Engineering, and Medicine of the United States, graduate students are at risk of suffering a mental health crisis across the country. Alan Leshner, who chaired the committee behind the report, says that "the problem is as big or bigger than ever, and it is not getting better. Unless there is concerted attention, the situation will get substantially worse because the pressures will not go away." This situation is aggravated by the fact that in many cases, the only person they turn to is their supervisors, added to the pressures of a family, work, personal nature, plus the pressure related to the development of activities of the postgraduate as the scientific production required for the dissemination of knowledge. One report of the American Council on Education revealed that "68% of university presidents recognize that the mental health of students is one of their most urgent problems" with a ... "... The dropout rate for students with problems of this type ranges from 43% to 68% " [23].

According to these studies, the students expressed uncertainty regarding their career, academic success, and social relationships, increasing stress, anxiety, and depression. An important aspect to mention is that various factors such as living in urban areas, with their parents, with a stable economic situation can prevent anxiety symptoms from developing in students. In the case of Colombia, a study conducted by the Colombian Association of Universities (*Ascún*) in which 15,841 students from 78 Higher Education Institutions (IES) participated; quoted in the newspaper *El Tiempo* on June 5, 2020. This study "revealed that the mental health of university students in the country had suffered a serious impact because of confinement, directly affecting aspects such as their self-esteem, the way they relate to others, as well as their academic performance. At least 55 percent of students report being more irritable or sad than before isolation, 48 percent have experienced intense feelings of loneliness, 38 percent have trouble making sense of life, and 34 percent recognize a decline in self-esteem" [24].

About the impact on the education of measures such as remote learning; the impact analysis, policy responses, and recommendations carried out by UNESCO and published in its document "COVID-19 and Higher Education: de the immediate effects of the day after" [16] shows that, globally, the main concerns are "social asylum, financial issues, internet connectivity and, in general, the pandemic-related anxiety situation." Particularly for Latin America, the main problems for students are “internet connectivity, financial issues, and difficulties in maintaining a regular schedule” since the school does not encourage self-regulation of learning processes.

Concerning teachers, the UNESCO study shows that many of them, having no previous experience in distance education, as well as having had an opportunity to receive related training, "have been appropriated from all non-face-to-face media available to develop what has been called emergency distance education or, also, Coronateaching" defined as a process of transformation of "... face-to-face classes in a virtual way, but without changing the curriculum or methodology." *Cielo Mancera*, head of the e-learning center of the Universidad del Rosario (Bogotá – Colombia), states that “Virtual education has its methodology in which the student is autonomous from his learning process and where he accesses previously prepared content. Remote access, which we are having at this juncture, is completely different because what universities are doing replaces their face-to-face model through digital resources." [25]. This situation is reflected with the low or virtually zero development of Virtual Learning Objects (OVA's), which include resources such as

videos, animations, images, and interactive documents whose previously developed content must contribute to the learning process and the autonomous development of knowledge.

It derives from an educational culture established on the face-to-face in which students have been immersed in an educational system based on work in the classroom for more than 11 years. Adopting different methodologies abruptly without obeying an educational policy requires studying how to meet this challenge without prejudice to academic quality.

1.2 Purpose of the study

This research work is motivated by the abrupt and disruptive change in the organizational modality of learning teaching processes, from a face-to-face scenario to a non-face-to-face scenario that, from a curricular point of view, was not contemplated, with impact in components of this curriculum as the instructional method "Problem Based Learning" used in the subject Metalworking Processes Workshop of the Industrial Engineering career, of the Faculty of Engineering of the National University of Colombia (Bogota), as in the didactic strategies applied in the course to promote learning strategies, the forms of evaluation and aspects related to the content of the course that, being a theoretical-practical subject, contemplates the realization of laboratory practices and industrial visits, that are totally restricted.

From the academic period 2018-03 (Second semester), implementing the Problem Based Learning methodology began in the Metalworking Processes Workshop course in face-to-face mode, based on the guidelines established for its development. This work continued until the academic period 2019-03 (Figure 4), with the corresponding improvements due to the experience acquired. The 2020-01 period began face-to-face from February 6 of that year. Unfortunately, the pandemic caused by Covid-19 resulted in an abrupt disruption of the course from March 18.

Because of that, the course had to be addressed in a non-face-to-face way without prior preparation in terms of logistics, technology, and training for most of the University's professors., with the derived implications.

In this way, the objective of this study is to establish the curricular changes and to develop an environment that allows the development of learning processes in a non-face-to-face mode based on the problem-based learning method. (PBL).

Figure 4. Example of Moodle platform of Metalmechanical Processes Workshop subject for academic semester 2018-03.

1.3 Problem statement

Due to the crisis generated by COVID 19, there was an abrupt and disruptive change from the organizational modality of face-to-face education to a non-face-to-face modality. Because of its current structure, the non-face-to-face modality does not respond adequately to different curriculum components such as the teaching strategies associated with the curriculum, the comprehensive training processes, and the academic and physical requirements to develop learning processes. In this way, based on a PBL established in principle for a physical environment in person and associated with a study plan, its development to a virtual environment is abruptly faced with different learning challenges for students, generated by the lockdown associated with the COVID -19, for which the academic community is not prepared. The learning challenges are related to a lack of social interaction impacting teamwork, the development of soft skills such as communication, the impossibility of carrying out the practical and experimental components of the subject, motivation, among other aspects. Other situations are related to the environmental conditions at home. Also, the impact on the emotional state and mood of the students, with manifestations of anxiety, depression, and loss of sleep quality; an educative system designed for face-to-face education, a situation that is not alien to the National University of Colombia where the development of Digital Educational Resources is incipient and does not allow to face the current situation. The effect is that there is no culture for the development of online learning activities, no teacher training processes have been developed for this modality of work, not in person in pedagogical aspects or technological aspects. Although there is a technological infrastructure related to ICTs in Colombia, the situation generated by COVID-19 has shown the inadequacy of internet connectivity in the country associated with geographical coverage. According to a study carried out by the Laboratory of Education Economics (LEE) of the Pontifical Javeriana University (Bogota) [26], 96% of the municipalities of Colombia do not have any resources or coverage for the development of virtual courses.

To date (September 2021), this situation has worsened in Colombia, as evidenced by the situation related to the scandal in the Ministry of Information and Communication Technologies (Mintic) on the alleged case of corruption in contracting for the implementation of free internet to 7000 rural schools [27].

On the other hand, the development of virtual education processes has not resulted from an implementation policy reflecting in a curriculum design for this work modality but as a circumstantial aspect to respond to the current crisis. About the quality of the Internet, according to Cable.co.uk's report, New America's Open Technology Institute, and Google Open-Source Research, Colombia ranked 131st globally in terms of internet speed [28]. By 2020 it ranks 119th, with a mean download speed of 8.80 Mbps versus, for example, the 85.03 Mbps mean download speed of Denmark at number 14 or 42.33 Mbps in Germany (Position 42). [29].

All the above contribute to the complex development of learning processes in a non-face-to-face mode. However, even when working with a method such as PBL, with the aggravation that there are no concessions of time, form, and or place, and the not taking into consideration in general, the students' learning preferences as an input for a curricular design adapted to an online environment.

1.4 Justification

This research work is justified as a mechanism that contributes to responding to how to develop and implement in a structured way learning processes in a non-in-person modality, generated by the disruption associated with COVID 19, a situation for which the national education system and the UN education system was not prepared. It seeks with this work, to generate a framework in which, from the development of processes framed in the problem-based learning method, the development or selection of strategies that allow adjusting the curriculum in its teaching, evaluation, and pedagogical fields.

2 Theoretical Framework

The following theoretical framework built is developed to establish epistemological and contextual support for the concepts and theoretical considerations on which the research developed in this Thesis oriented to the "Application of Problem-Based Learning in a non-face-to-face modality in crisis situations, based on the changes required to promote the associated learning process."

Based on the relationship between learning and emotions, as well as the disruption produced by the abrupt change from a face-to-face to non-face-to-face learning modality, caused by the pandemic produced by Covid 19; and its possible impact on the problem-based learning methodology (PBL), used in the development of the course "Workshop on Metalworking Processes" (case study in this Thesis); concepts and themes related to emotions and learning, PBL, PBL Online, Personal Learning Environments (PLE) and Learning Styles will be addressed. It will demonstrate how the PBL methodology can be developed in non-face-to-face modality from these elements' interaction.

2.1 Problem Based Learning (PBL)

The concept of PBL is not new, and since its conception in the 1960s in the last century at McMaster University (Canada), it was founded on a curriculum transformation organized around problem-solving. For *[30]*, PBL is "a pedagogical experience to investigate and solve problems that arise ... in the real world." It also proposes that "it is an organizer of the curriculum and also a teaching strategy." De Graaff and Kolmos cite in *[31]*, concepts such as those shown in Table 1:

Author	Definition
Barrows, H.	Define PBL in "terms of specific attributes as being student-centered, taking place in small groups with the teacher acting as a facilitator, and being organized around problems." ([31])
Gijselaers	Defines PBL "in relation to theoretical learning principles, such as learning as the construction of knowledge, meta-learning, and contextual learning."
Savin-Baden	Describes "five different models of PBL resting on five different views of the objective of PBL, including the perception of knowledge, learning, problems, students, teacher roles, and assessment."

Table 1 PBL concepts (Adapted from [31])

Constructivist theory is the fundamental basis of problem-based learning as it is characterized by giving the student an active and self-directed role in building his own knowledge in interaction with the environment and based on his previous knowledge. William Glaser (quoted in [32]) states three principles related to learning and cognitive processes: - value it as a system in construction with active student participation, - metacognition and – its social character.; principles consistent with-it constructivism. In this way, PBL privileges active learning, encourage the construction of knowledge by students, which must privilege the development of metacognitive processes that allow the student to "perform actions aimed at knowing their mental operations and processes (what), know how to use them (how) and know how to read them and or change them when required by the proposed goals" [33]. Thus, the metacognition relationship with PBL is established to the student to participate intentionally and actively in the direction of his learning in a self-regulated way, where he is the one who is directed to the achievement of a goal and controls the process (Arguelles and Nagles 2007 cited in [33]).

PBL develops the learning process to achieve the intended learning outcomes around searching for a problem. This problem can arise from a theoretical approach stemming from the experience and knowledge of the teacher or a situation (past or present) arising from a work context or the professional exercise of discipline. Thus, the problems raised represent situations that students will subsequently face during their profession. Another characteristic of PBL is the development of activities in small groups, which favors teamwork, collaborative learning, self-regulation, self-critical sense, and soft skills such as communication, among other aspects. It is observed, in this way, that the constructivism-problem-based learning relationship is synergistic.

Due to the current confinement situation, the development of the PBL, as a teaching method, is hindered by the restriction on social interaction, characteristic of this learning method. It is, therefore, necessary to apply the PBL in a non-face-to-face modality or, in an online way, as the only current actual alternative, for the development of the learning process.

2.2 PBL Online

According to the 2017 study developed by the firm Deloitte, *[34]* trends in human capital, shown as the accelerated technological change (in particular, digital transformation), has created gaps concerning the ability to absorb and incorporate the different advances by individuals, organizations, and government agencies (Figure 5).

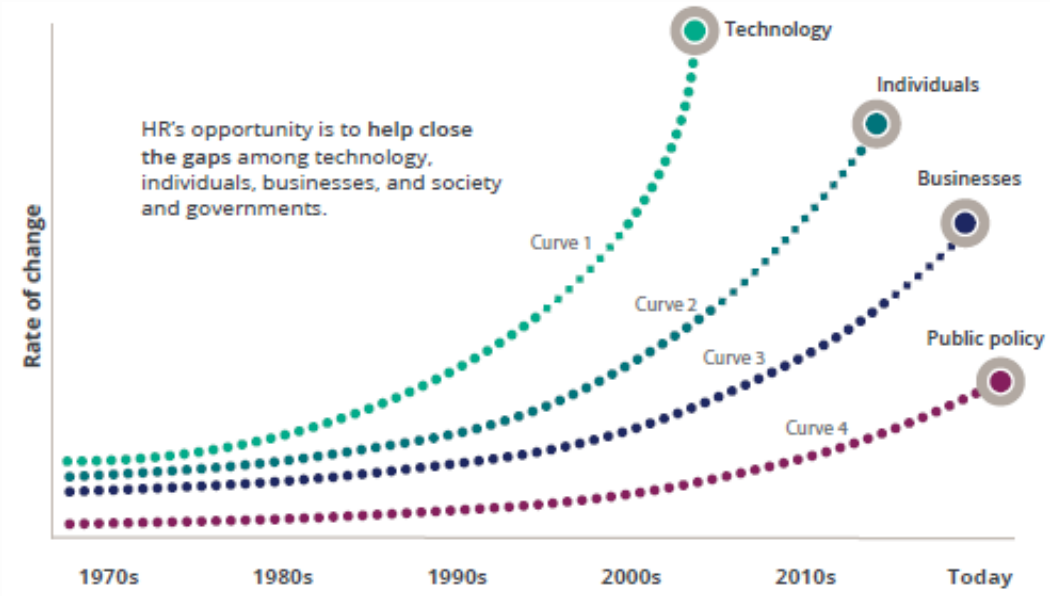


Figure 5 Study of human capital trends. (Taken from [34])

These gaps have also been shown by Yannis C Yortsos, dean of the School of Engineering of the University of Southern California [35], when in 2017 he warned how the increase in technological development generates disruptions in society so that individuals and organizations require agility and adaptability to reinvent themselves and not lose relevance. (Figure 6).

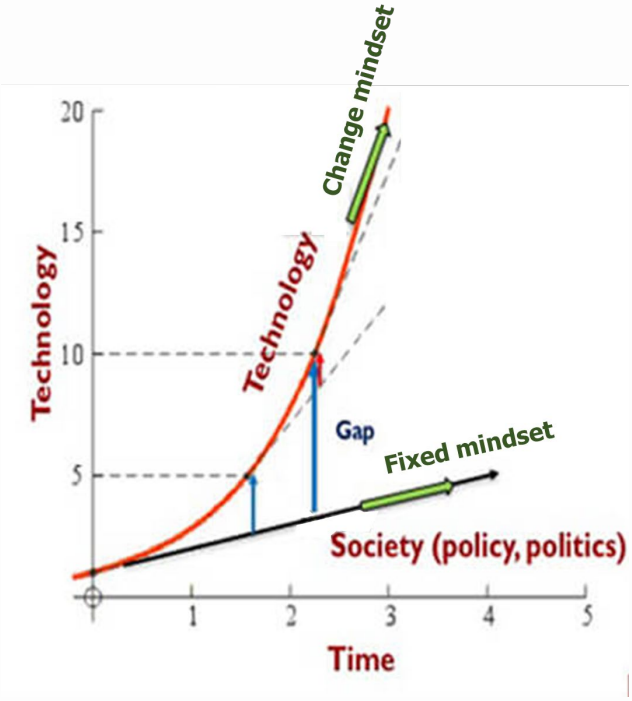


Figure 6 Social disruption associated with technological development (Adapted from [35] and [36])

Since 1998, in coincidence with the studies of Deolitte and Yortsos, he stated in [37] that "The higher education of the future, taking on the challenge of the dizzying development of sciences and technologies, must emphasize basic and general training and prioritize learning processes, so that the future graduate or graduate is endowed with the intellectual resources to continue to educate itself. It means that the education provided to you must stimulate your creativity and imagination".

Therefore, the growth of knowledge associated with technological development is also exponential and exceeds the ability of the education system to adjust its curricula to this growth. For Gonzalez (2004) cited in [38], over the past ten years, the amount of knowledge has doubled, and according to the American Training and Documentation Society, it doubles every 18 months. Thus, the half-life of knowledge, understood as the time elapsed since knowledge is acquired to the moment when it is obsolete is an influential factor that establishes a challenge that forces the generation of new forms of instruction.

These gaps related to knowledge in Colombia are present in higher education, which, to address this phenomenon, must implement online learning processes based on government or institutional policies as a complement to face-to-face teaching. Furthermore, with the current confinement situation by COVID-19, the non-face-to-face learning modality becomes relevant as it is the only mechanism available to activate educational processes.

Just as the PBL is based on the constructivist theory of knowledge, its integration into an online environment must include the concept of connectivism as an essential component. Connectivism is the learning theory of the digital age. [39]. This theory, developed by George Siemens and Stephen Downes, places learning in a digital environment continuously evolving with accelerated technological development. For Siemens, connectivism addresses learning in complex, social, and networked environments" and defines connectivism [38] as "the integration of principles explored by chaos, network, and complexity and self-organization theories. Learning is a process that occurs within nebulous environments of shifting core elements – not entirely under the control of the individual. Learning (defined as actionable knowledge) can reside outside of ourselves (within an organization or a database), is focused on connecting specialized information sets, and the connections that enable us to learn more are more important than our current state of knowing. Connectivism is driven by the understanding that decisions are based on rapidly altering foundations. New information is continually being acquired. The ability to draw distinctions between important and

unimportant information is vital. The ability to recognize when new information alters the landscape based on decisions made yesterday is also critical".

Connectivism encompasses individual and collaborative learning processes. Personal knowledge is described as a network that feeds organizations and institutions, giving feedback to the network and energizes learning. Knowledge consists of information nodes that are a network when they share resources. The ability to create and interact on these networks constitutes learning. [40].

On the other hand, a learning community, from the perspective of connectivism, is observed as a node in which students "will connect to a network to share and find new information, will modify their beliefs based on new learning, and will then link to a network to share these realizations and discover further information once more [41].

From a connectivism perspective, learning occurs when connections between ideas, concepts, opinions, and views are made, with technology having a pivotal role in facilitating the connections necessary for developing learning. Dunaway (2011), cited in [40], states that four practices are required to achieve connectivism:

1. Provide students with traditional information sources (libraries, academic resources), collaborative Web 2.0 technologies, and teacher-generated content.
2. Place these in an instructional structure that includes personal learning networks.
3. Leverage the skills they can transfer to expand learning networks.
4. Develop a dynamic, technology-based knowledge community and learning network. In this community, students critically evaluate and synthesize concepts, opinions, and perspectives.

For connectivism, learning can be acquired outside formal educational environments and uses constructivism to develop learning teaching processes. In this way, PBL can be developed in a non-face-to-face digital environment.

It can then relate connectivism to online PBL. First, by giving the student responsibility for their learning process and knowledge generation, second for the possibility of interacting through digital learning communities, third by the teacher's mediation as a tutor and facilitator and as an energizer of virtual spaces as proposed by Dunaway. Finally, it is important to mention that the role of the teacher as tutor/facilitator is a critical success factor for the achievement of learning processes in non-face-to-face learning modality based on the PBL.

Smidt et al. [42], propose an interaction model that allows integrating connectivism with the PBL. Figure 7 shows the roles of each element. The PBL integrates learning objectives, while connectivism establishes the digital procedural structure to achieve online learning goals. Finally, the relevance of learning must be given by contextualizing content and technology to value learning from the students' relationship with the environment.

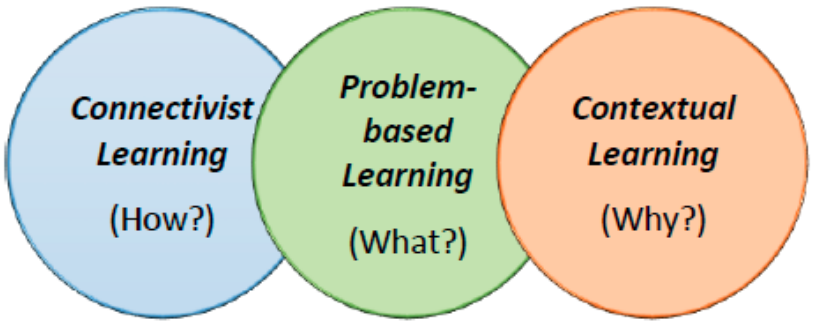


Figure 7 Pillars of learning model [Adapted from [42]

2.3 Personal Learning Environments (PLE)

The disruption caused by COVID 19 in the learning modality across the world has forced students to use only one form of non-face-to-face academic work, mediated by the mandatory use of ICT's and different resources and tools necessary for the development of educational activities at home. Under this landscape, a key component required is the Personal Learning Environment (PLE).

2.3.1 PLE Defined

PBL is a methodology in which the students acquire knowledge through self-learning activities and interaction with others searching for a problem solution. These characteristics are compatible with Dunaway's practices. In this way, a path to provide collaborative Web 2.0 technologies, an instructional structure based on learning networks, and the possibility to develop learning through these virtual community spaces, are the Personal Learning Environments or PBL. On the other hand, PLE "is usually linked with sociocultural, constructivist and connectivist theories of learning" [43]

There are different definitions related to the meaning of a PLE. For [44], it is a digital space that a person can access to create, add, store, and share materials for learning; he also ate to interact socially with others. It is a set of elements used to manage personal learning, through which an "intentional and deliberate integration of formal and informal learning spaces" is established [45]. Regardless of the concept, there is a common element in these definitions. That is the control given to the student over their learning process, according to Martindale and Dowdy in [46].

PLE is defined according to two approaches:

- Pedagogical: Addresses the PLE as an educational methodology that promotes self-learning through the use of Web resources (Cabero et al., 2011:4, quoted in [47]) that include among other "learning tools, materials, instruments, services, and artifacts from numerous contexts and environments to be used by the student" [45]. This approach is characterized by the active role that the student assumes in a self-regulated learning process controlled by him in terms of objectives, content, process, activity management, and interaction with others [48].

- Technological: it perceives it as a "software platform composed of a repository of contents and different management and communication tools" (Cabero et al., 2011: 4, quoted in [47].

2.3.2 PLE Building Elements

In general, in line with [49], a PLE consists of:

- Resources and or sources of information such as repositories, virtual libraries, databases, and others. Supporting elements for developing and designing teaching processes

- A set of tools such as wikis, blogs, RSS feeds, multimedia, teaching platforms, e-learning; placed in a virtual educational environment that establishes services or tools for managing materials, resources, and learning relationships. A proposed classification of these tools is search, communication, creation, simulation, collaboration, and evaluation tools.
- A personal learning network. For students, to communicate directly or indirectly for exchanges, learning communities; based on the learning objectives, course content, and Internet use.

A model of PLE is shown in Figure 8 [43]. This model divides a PLE into four constituent elements related to the learning process: personal, learning, environment, and network.

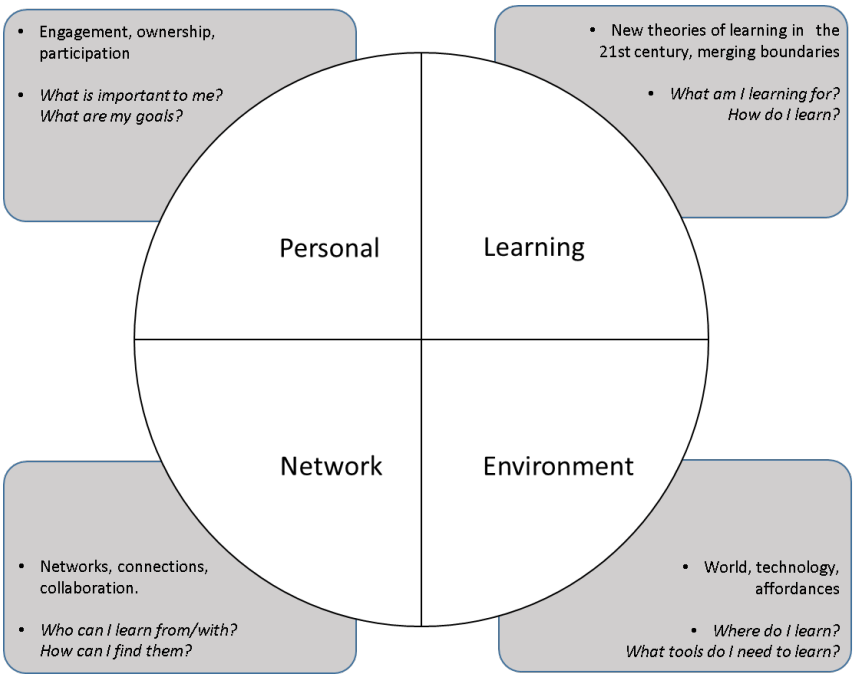


Figure 8 Components of the PLE model (Taken from [43])

2.4 Learning Styles

Through PLEs, students build their own learning spaces according to their learning preferences, motivations, preferred learning techniques, among others. In other words, they can develop their PLE according to their learning styles. There is a wide range of concepts about what learning style means. Table 2 shows a review of definitions cited in [50].

Author	Definition
Della-Dora and Blanchard (1979)	"a personally preferred way of dealing with information and experiences for learning that crosses content areas. "
Claxton and Rolston (1978)	"the student's consistent way of responding and using stimuli in the context of learning."
David Kolb (1984)	"a result of hereditary equipment, past experience, and the demands of the present environment combining to produce individual orientations that give differential emphasis to the four basic learning modes postulated in experiential learning theory."
Anthony F. Gregorc (1979)	"consists of distinctive, observable behaviors that provide clues to the functioning of people's minds and how they relate to the world."
David E. Hunt (1981)	"describes students in terms of those educational conditions under which they are most likely to learn and essentially describes the amount of structure individuals require."
Ronald R. Schmeck (1988)	"is the product of the organization of a group of information processing activities that individuals prefer to engage in when confronted with a learning task."

Table 2 What learning style means (Adapted from [50])

Learning style deal with the way different people addresses their learning. Although its application has been questioned, maybe by the commercial approach in which the concept has been immersed and promoted by an "industry" dedicated to the publication of tests and guides and or because learning has not been shown to improve by aligning activities with learning styles, for years, from studies, attempts have been made to establish this connection [51]. Educational psychology has adopted it and generated reviews reflected in specialized books of this discipline of knowledge. For example, Jeanne Ellis Omrod, educational psychologist, cited in [52], wrote in 2008, "Some cognitive styles and dispositions do seem to influence how and what students learn. . .For example, some students seem to learn better when information is presented through words (verbal learners), whereas others seem to learn better when it's presented through pictures (visual learners)."

According to Coffield (2004 cited in [51], more than 70 learning styles schemes are. In [53], an impressive inventory of methods referred to in different articles is carried out. Table 3 shows the relationship between the models and their corresponding taxonomy:

Model	Curry (1987)				Riding and Cheema (1991)	Rayner and Riding (1997)		
	Instructional preference	Social interaction	Information processing	Cognitive personality	Wholist–analytic	Personality centred	Cognitive centred	Learning centred
Witkin (1962) Field-dependence/independence				●	●		●	
Kagan (1965) Impulsivity–reflexivity				●	●		●	
Holzman and Klein (1954) Leveller–sharpener				●	●		●	
Pask (1972) Holist–serialist				●	●		●	
Pavio (1971) Verbaliser–visualiser				●			●	
Gregorc (1982) Style delineator				●	●		●	
Kauffmann (1979) Assimilator–explorer				●	●		●	
Kirton (1994) Adaption–innovation				●	●		●	
Allinson and Hayes (1996) Intuition–analysis				●	●		●	
Kolb (1984) ELM			●					●
Honey and Mumford (1992) LSQ			●					●
Vermunt (1994) LSI			●					●
Entwistle & Tait (1995) Surface–deep			●					●
Biggs et al. (2001) SPQ			●					●
Schmeck et al. (1991) ILP			●					●
Hunt, Butler, Noy, and Rosser (1978) Conceptual level			●					●
Dunn, Dunn, and Price (1989) LSI	●	●						●
Reichmann and Grasha (1974) Styles of learning interaction model	●	●						●
Ramirez and Castenada (1974) Child rating form	●	●		●				●
Reinert (1976) ELSIE				●				●
Hill (1976) Cognitive Style Interest Inventory				●				●
Letteri (1980) Learner types				●				●
Keefe and Monks (1986) Learning style profile	●	●		●				●

Table 3 Taxonomy of learning style models (Adapted from [53])

Based on the exposed taxonomy, as part of the development of this Thesis, Kolb's model was selected due to the following aspects:

- It allows organizing a course using a learning cycle, whose stages are associated with different learning styles.
- It focuses on learning [53] and information processing [53] - Table 3.
- There is a relationship between the experiential learning cycle, developed by Kolb, and problem-based learning.
- As a theory, it offers an approach to teaching-learning as a life-long process based on social and cognitive psychology. (Zuber-Skerritt, cited in [54])
- According to [55], "Learning is the process whereby knowledge is created through the transformation of experience."

Findings such as those reported in [56] and [57], show that the combination of PBL and ELT successfully develops critical knowledge and understanding in students. It also constitutes an effective means of developing participation and learning from implementing collaborative and autonomous work strategies. This situation leads to meaningful learning processes, in which knowledge is developed based on experience. This significant learning is achieved from the relationship established between the student's prior knowledge

and the “new knowledge” that he learns, fundamental for solving problems with the incorporation of experience.

According to Kolb (Cited in [58]), learning is defined as “the process by which knowledge is created through the transformation of experiences. Thus, knowledge is the result of the combination of understanding and change of experience. "In this way, a subject captures information that, during the learning process, transforms into expertise based on the interpretation and action that they perform on this information, from reasoning, analysis, and decision making.

How experience is captured, based on the model established with Experience Learning Theory (ELT), is established through two dialectically related modes [58]:

- Concrete Experience (CE): It is associated with carrying out an activity
- Abstract Conceptualization (AC): Development of the activity from the application of the related theory.

On the other hand, the experience is transformed through two dialectically related modes:
- Reflective Observation (RO): Reflection on the development of feedback from successes and failures.
- Active Experimentation (AE): Practical applications or solutions.

These dialectical modes are thus, distributed according to two dimensions:
- Processing: Involves the Active Experimentation (Doing) and Reflective Observation (Watching) stages
- Perception: Involves the Concrete Experience (Feeling) and Abstract Conceptualization (Thinking) stages

The structure of the cycle with its dialectical modes and dimensions is shown in Figure 9.

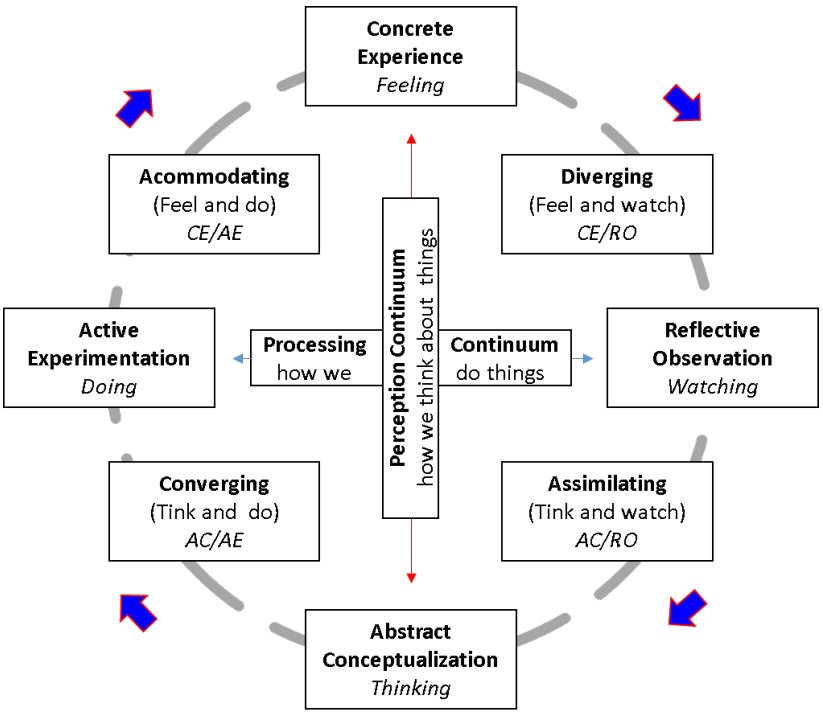


Figure 9 Kolb´s Cycle. (Adapted from [58])

It is observed how learning is sought to arise from the confrontation between action (AE) / reflection (RO) or how we do something; and experience (CE) / abstraction (AC) or how we think about things. The student,

therefore, must approach the four dialectical modes in a continuous cycle. In this process, they will cross stages mediated by what they feel and observe (CE / RO), think and keep (AC / RO), think and do (AC / AE), and feel and do (CE / AE). These stages place the student in various forms or particular styles, which based on the above are:

- Diverging (Feel and watch - CE / RO)
- Assimilating (Think and watch - AC / RO)
- Converging (Think and do - AC / AE)
- Accommodating (Feel and do - CE / AE)

The student's circulation through these styles and the dialectical dimensions of processing and perception should be promoted through the teaching-learning process. According to [55], the experiential learning cycle is established as a central model and is related through concentric circles with other conceptions, of which the one associated with problem-solving is of particular interest. (Figure 10).

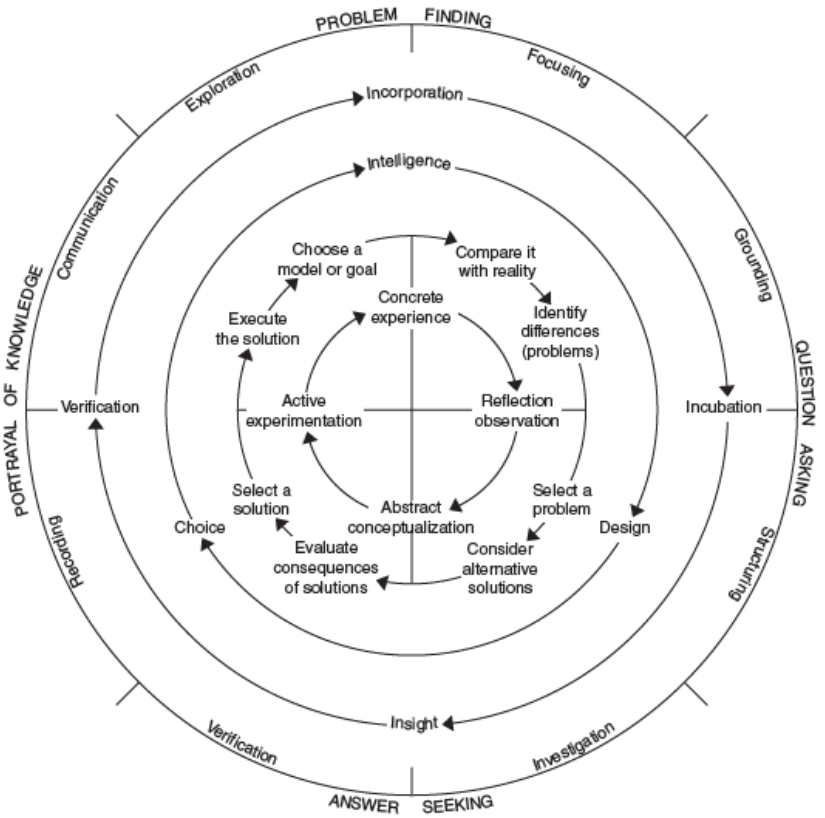


Figure 10 "Similarities Among Conceptions of Basic Adaptive Processes: Inquiry/Research, Creativity, Decision Making, Problem Solving, Learning" (Taken from [55])

As can be seen, as a fundamental aspect, the search for a problem is associated with the Concrete Experience of Kolb's experiential learning cycle. In this way, this cycle is consistent with the stages related to the problem-solving cycle and the Inquiry / Research cycle and can be considered a starting point for the learning process. Table 4 shows the relationship between the concepts mentioned:

Cycle				
ELC (Kolb)	Concrete Experience (CE)	Reflective Observation (RO)	Abstract conceptualization (AC)	Active Experience (AE)
Problem-solving	Compare with reality, Identify problems	Select a problem, Consider alternative solutions	Evaluate consequences of solutions, Select a solution	Execute the solution, choose a model or goal (Feedback and go again to CE)
Inquiry Research	Problem Finding	Question Asking	Answer Seeking	Portrayal of Knowledge

Table 4 Relationship between the concepts (Adapted from [55])

Other models identified from previous studies [59] allow the identification of learning styles, such as the Salmes, Felder-Silverman, and VARK models.

In particular, the VARK model, developed by Neil Fleming and Colleen Mills (2006), seeks to determine the preference of students to process information from a sensory point of view [59] [60]. VARK is the acronym for the initial letters of sensory modal preferences:

- Visual: The information is presented through graphs, tables, figures, and symbols
- Read / Write: Interpretation of information in the form of printed or online texts
- Aural: Information is perceived aurally (discussion and listening)
- Kinesthetic: Based on experience and practice; real or simulated [59].

According to Prithard (2205) cited in [61], good learning is not limited to the student's learning sty but depends on the teaching materials used. Therefore, the preceding acquires special relevance for non-face-to-face learning since this modality requires tools or instruments that facilitate and motivate students to learn based on ICTs.

However, the VARK model has been questioned in different studies (For example, [62] [63]). These studies show that learning outcomes are not necessarily better if instruments are implemented aligned with a person's learning style. In addition, the questioning related to the fact of whether most of the serious learning takes place in the classroom or different spaces such as those associated with online learning, in which self-learning plays a preponderant role (according to Polly Hussman and Valerie Dean O'Loughlin (Cited in [64])). Thus, the importance of determining the learning styles of each student and how he selects the study strategies that most favor him to achieve the learning objectives successfully [73] is highlighted, but more from the point of view of being observed as preferences to develop specific didactic proposals on this basis.

3 Research Context

3.1 Objective Population and Subject

This study will be carried out with 27 students of the Workshop of Metal mechanical Processes course of the Industrial Engineering program of the Department of Systems Engineering and Industrial (Faculty of Engineering – National University of Colombia), taught in the fifth semester of the career. The course description is as follows:

Course Name: Metal mechanical Process Workshop

Component: Discipline

Grouping:	Materials and Processes
Semester:	Fifth (5th)
Credits:	Three (3)

3.1.1 The general objective of the subject

The students must have the capacity to establish and analyze the different activities of an industrial process (manufacturing sequences) required to obtain a product, from the development of the concepts associated with the mechanisms related to the transformation of the materials and the administration of the processes.

3.1.2 Instructional method

The course will be developed through the instructional method of Problem-Based Learning. For this purpose, each group of students must establish the metalworking manufacturing processes required to manufacture an object, which they will select at the beginning of the course.

3.2 Group formation

The students are free to conform to the work teams and select the members for each group. Regarding the determination of the size of the groups, it is established [65] that, when the groups are of a few members, there is a risk that the potential for work will be disinterred or lost if one of its members with draws. On the other hand, large groups run the risk of one or more members lagging and not contribute to the development of work. Based on a survey conducted by Tood cited in [65], 48% of respondents prefer groups between 4 and 6 members. A study on the optimal equipment size to work in collaborative environments [66] concludes that four (4) members must be the size. Based on the above and my teaching experience, it is defined that the size of the groups for the development of this study is four students.

3.3 Project

The project to develop for the students consists of the following components, according to the course syllabus. (Appendix 1)

- Preliminary technological analysis of the object selected. This analysis allows us to know an object exhaustively from the study of each of its constituent parts. The technological analysis allows us to understand the different aspects that converge in the genesis and development of a technological object in all its complexity systematically and relationally. The components that must include this analysis are morphological, functional, technical, economic, sociological, and historical analysis. For this analysis, the students must develop their learning related to fundamental topics of processes and manufacturing processes.
- Design and establish logically and technically the sequences and activities required to obtain the object through the transformations of raw materials, doing a process planning.
- Knowledge of the different types of processes to have the capacity to select the good manufacturing process according to with a desired kind of transformation from the formal point of view, as in compliment of different technical specifications of the object. All that is in concordance with the process planning established.
- Adjust technological analysis, the final definition of the process planning, and documentation of the manufacturing process required to produce the object.

3.4 Project activities

The Metalworking Process Workshop course will be held for 16 weeks between August 25, 2020, and December 11, 2020, under the University's academic programming. For the development of the subject, each group of students will select an object to develop a manufacturing project. For the project-related object, each group will establish a set of problems that they will define based on the course syllabus. Thus, they will develop questions for the generation of the manufacturing project, which must be answered to solve the specific problems of manufacturing from the conceptual development and production of knowledge. Three weekly sessions of two hours will be held each.

Problem 1: It is associated with the technological analysis of an object (preliminary). Students will need to conceptualize processes, manufacturing, production systems, process characteristics (flow, efficiency, effectiveness, cost, cycle time), classification of manufacturing processes, productivity, added value, and process diagrams for this analysis. Weeks 1 to 3

Problem 2: It is related to the preliminary definition of the manufacturing process. The students must generate knowledge related to the definition of machining accuracy, part drawing analysis, the decision between making and buy, engineering change notes, critical dimensions, materials evaluation, and process selection. An important aspect is the development of knowledge associated with process documentation and the generation of manufacturing sheets. Feedback and improvement of Technological Analysis. Weeks 4 a 6

Problem 3: To learn about specific manufacturing processes. The students will select, depending on the components of the object. The particular processes required for your manufacture. Weeks 7 a 14. Feedback and improvement both of Technological Analysis and Planning Process. The development of the manufacturing range is included.

Problem 4: Learn to establish the manufacturing costs of the manufacturing processes. The learning related to this problem will be done from week seven and will culminate in week 15 with the complete definition of the manufacturing process with its associated documentation.

Problem 5: Learn to determine manufacturing compliance through measurement processes. As in issue 4, the learning related to this issue will be done from week seven and will culminate in week 15 with the complete definition of the manufacturing process with its associated documentation.

In Appendix 2, a format with the structure of the reports to be presented is indicated. It also describes the methodology for solving problems raised under the PBL and is related to the technological objects assigned to each workgroup. Each problematic situation is connected to a THEMATIC AXIS, on which the PBL will be applied.

The corresponding evaluation process will be carried when the different problems are solved.

The structure of the evaluation process is:

- First component: Exposure of advances through Zoom © with each working group (with recording), plus evidence of collaborative learning through each student's Personal Learning Environment (Platform Online Symballo ©), as the activity in the learning community in Currents © of Google Apps ©, and the meeting records made by Zoom © (50% of each assessment)

- Second component: Online evaluation through Moodle platform © (50% in each assessment)

The advances will be placed previously on the Moodle platform of Colombia National University and video recordings on Google Drive© and Zoom© File.

3.5 Type of Research

The type of research is cualitative. Different aspects establish the need to use this type of research:

- The study is carried out with a limited group of students from the course "Metalworking Process Workshop" for the 2020-02 semester (27 students). In this way, the qualitative approach will allow the study of the research problem with this group of students.
- From a qualitative point of view, we will work with a larger group of students to whom the same data collection instruments have been applied during the 2020-01 semester. Then, based on the statistical analysis, this proposal will be validated.
- A qualitative approach will be approached in search of a greater understanding of the research problem.

3.5.1 General Objective

Determine and implement the curriculum changes required to apply the method (PBL) in a non-face-to-face modality because of the abrupt disruption in the learning modality caused by COVID-19 as the necessary elements to develop the virtual environment to promote the learning process associated.

3.5.2 Specific objectives

- SO1 - Make a diagnosis of the effects generated in the learning-teaching processes by the abrupt change from face-to-face learning modality to non-face-to-face.
- SO2 - Establish the impact of the effects found on the problem-based learning application.
- SO3 - Determine the learning preferences of students in the subject Workshop of Metalworking Processes
- SO4 - Diagnose how autonomous learning and collaborative learning have developed in a disruptive non-in-person modality.
- SO5 - Determine teaching strategies and digital educational resources (texts, images, audios, infographics, OVA, and videos) that, in non-face-to-face mode, allow us to generate capacities like the face-to-face activities associated with problem-based learning, based on students' learning preferences.

3.5.3 Research Questions

Is it feasible to develop the learning process with PBL in a non-face-to-face modality through curriculum changes based on a virtual environment designed and implemented to promote learning, having in account technology (ICTs) and the students' learning style?

- RQ1 - How has the students' learning process been affected by the transition from a face-to-face environment to a non-face-to-face one?
- RQ2 - What factors have affected students' interest in knowledge acquisition and capacity building with the non-face-to-face learning modality?
- RQ3 - What are the students' learning preferences?
- RQ4 - How do students' learning preferences affect the development of online problem-based learning (PBL) methodology?

- RQ5 - How do learning preferences influence students' interest in learning in a non-face-to-face mode?
- RQ6 - What non-face-to-face strategies can replace face-to-face methods required for problem-based learning?

3.5.4 Hypothesis:

- H1 - The implementation of changes at the curriculum level (teaching methods, adjustments in the course program, comprehensive training), pedagogical (forms of evaluation, didactic) allow to develop of the methodology of learning based on problems in a modality of non-face-to-face teaching and favor autonomous learning, collaborative learning and social building of knowledge.
- H2 - The development and implementation of Personal Learning Environments, including digital educational resources, enables adequate development of problem-based learning in non-face-to-face mode.
- H3 - The personalization of digital educational resources, based on students' learning preferences, generates positive emotions towards the processes of learning from problem-solving.

3.5.5 Variables:

VARIABLE: PBL online	
Denomination:	Problem-based learning in non-face-to-face mode
Type:	Qualitative
Nature:	Dependent
Instrument:	Semistructured interview - Survey Learning community.

Se establece el PBL in non-face-to-face mode como variable dependiente, ya que debido a la situación de crisis se hace necesario desarrollar cambios que permitan transformar aspectos metodológicos, tecnológicos y curriculares de la aplicación del PBL que se desarrolla para el curso Taller de Procesos Metalmecánicos desde el semestre 2018-03 (Segundo semestre) hasta el inició de la pandemia (2010-03). Esta dependencia se establece a partir de la forma como los cambios realizados, impactarán en aspectos fundamentales para el desarrollo de esta metodología, tales como Autonomous Learning, Collaborative Learning, solving problems, etc.

VARIABLE: Curriculum	
Denomination:	Curricular changes
Type:	Qualitative
Nature:	Independent
Instrument:	From survey related with AL and CL

Como mecanismo para determinar la aplicación del PBL Online, se deben realizar cambios curriculares es aspectos específicos como syllabus, metodologías didácticas y de evaluación, recursos académicos y físicos. El tipo de cambios estará sujeto a los resultados e información obtenida de la aplicación de los diferentes instrumentos con base en preferencias de aprendizaje y percepciones sobre la formación virtual. Estos cambios se relacionan con modificaciones para adecuar la metodología PBL a un entorno Online.

VARIABLE: Technology	
Denomination:	Technological requirements
Type:	Qualitative
Nature:	Independent
Instrument:	Data from Moodle ©, Google Drive ©, etc

Un pilar fundamental para el desarrollo del PBL Online se relaciona con la tecnología requerida. Esta se puede definir como tecnología dura constituida por computadores y otros medios de comunicación como tabletas y dispositivos móviles, redes de internet y de comunicación telefónica; y red de energía eléctrica. La tecnología blanda se relacionará con software especializado, simuladores, plataformas de comunicación virtual (por ejemplo Google Meet ©, Zoom ©, Moodle ©), espacios personales de aprendizaje (como Symbaloo, Google Drive ©); como también tableros digitales, Suite de Microsoft Office © (PowerPoint ©, Excel ©, Word ©). Lo anterior con el objetivo de suplir actividades de carácter presencial relacionadas con la metodología PBL. La determinación final de los diferentes cambios estará sujeta a los resultados que se obtengan de encuestas y entrevistas.

3.6 Research Methodology

The research methodology is related with case study. In particular, the study will be addressed to the group of students of the Metalworking Process Workshop subject of the Industrial Engineering program of the Faculty of Engineering of the National University of Colombia. They are studying the subject during the academic period 2020-02. Interviews, surveys and observation will be carried out based on the activities proposed for students related to the objectives of this research.

3.7 Instruments

The following instruments were developed and or selected:

- Semi-structured interview
- Perception survey on autonomous learning
- Collaborative learning perception survey
- Survey on learning preferences

3.7.1 Semi-structured interviews:

The learning process is a social reality that requires knowledge from the students, events, and subjective aspects that include opinions, attitudes, values; related to specific situations. For this work, it is important to know, from the point of view of the students in a condition of confinement generated by COVID-19, that has "forced" them to carry out learning teaching activities in non-face-to-face modality, as a single alternative; his opinions related to technological aspects (ICTs), emotional, curriculum, PBL, and social and home environment associated with online learning. The use of semi-structured interviews will allow investigating these subjective aspects. For this, a set of questions to be used will be defined previously, with the flexibility to modify their sequence and formulation depending on the person being interviewed. This will allow to deep into relevant topics, possibly asking new questions.

A semi-structured pilot interview will be applied with students from the 2020-01 academic period of the Metalworking Process Workshop and Introduction to Industrial Engineering subjects. Based on the results, the instrument will be refined to interview at the end of the Metalworking Processes Workshop course of the 2020-02 academic period. The adjusted questionnaire is shown in Appendix 3.

3.7.2 Surveys

Four preliminary surveys were implemented through Google Forms. These surveys are:

- Perception Questionnaire on Autonomous Learning and Collaborative Learning (Integrated) (Appendix 4)
- Learning preferences Questionnaires (Appendix 5)

The interviews will be applied to the students of the Metalworking Processes Workshop during the 2020-01 academic period and the students of the same subject at the beginning and end of the 2020-02 academic period

3.8 Additional instruments were used to collect data.

3.8.1 Session recordings:

The session recordings correspond to activities related to collaborative learning, autonomous learning, and course sessions. The video clips will be made during the development of the class sessions, as by the students in asynchronous sessions.

3.8.2 Community – Currents

A space will be established in Currents © by Google © where students can interact voluntarily with topics related to the subject, share content, discuss doubts, etc.

3.8.3 PLEs for each student

Each student will be asked to voluntarily create a personal learning environment (PLE) to locate different content, videos; for their personal use and as a repository of their activities in the subject.

4 Analysis and Results

Next, the results related to the diagnosis made will be observed to determine the effects on the teaching-learning process associated with the abrupt change to a non-face-to-face modality and the learning preferences of the students of the subject.

4.1 Pilot Semistructured Interview and Modified Interview.

An initial pilot interview was developed with students of the Metalmechanical Process Workshop (10 students) and Introduction to Industrial Engineering (2 students) courses from 2020-01. The interviews lasted an average of 40 minutes.

Based on the results of these interviews, the following situations were evident:

1. Extensive statements of the questions tended to confuse students.
2. Questions that generated duplicate answers

3. Questions that do not contribute to the search for information required for the development of the Thesis.

It has allowed me to rethink and adjust the interview, which was applied during the 2020-2 semester. The semi structured modified interview is shown in Appendix 3.

The following categories were established as a basis for the structure of the interview:

- Technology
- Pedagogy
- Curriculum
- Evaluation

Interviews were conducted with students of the Metalworking Processes Workshop subject group. The following aspects were the most relevant and commented on by the students during the interview for each question. The transcription of the interviews is in Appendix 6. With the results of the interviews, the specific objectives SO1 and SO2 were achieved:

Q1-Do you have in your home equipment to develop your learning in non-face-to-face mode? (PC, Laptop, Tablet, Mobile Phones, type, quantity, availability)

Most of the students have a computer and a cell phone. However, only one student of the interviewees benefited from the Welfare Directorate of the Faculty of Engineering of the University's support, with the supply of a tablet to develop his academic activity since he did not have a computer.

Q2- How has the technological component influenced the activities related to your learning process?

The most recurrent manifestations were the lack of capacity of the computers to carry out activities with specialized software, where the processor, processing speed, and RAM requirements were fundamental. As a result, those students worked with tablets and expressed limitations to developing activities because of technical restrictions. In addition, there was an impossibility of interacting with teachers and colleagues during virtual sessions, as there are no pens with pens that privilege this possibility.

All the above limited the adequate performance of academic processes and teaching-learning in non-face-to-face mode.

Another aspect manifested, not directly related to technology, is the workspace at home, as it is not designed for academic activities and interruptions due to home activities and interactions with family members.

Q3 - What can comment on regarding the availability, access, and quality of the internet connection (Data plan available, browsing speed, stability)

Although the students stated that they had internet availability, various situations arose, such as low navigation capacity that forced families to make investments in contracting plans with greater capacity, instability in the signal, congestion, and the impact on the service due to Power outages that disabled the possibility of using technology and interrupted non-face-to-face teaching-learning processes. This situation was more critical for students outside the capital city, intermediate towns, or countryside. This is associated with poor coverage and connectivity in these areas due to a lack of development and implementation of the required infrastructure. According to [67], Colombia ranks 65th in Fixed Broadband, with 68.44 Mbps, compared to the top ten countries with speeds higher than 200 Mbps. Browsing through mobile devices ranks 123rd with 18.67 Mbps, compared to the first ten countries with rates above 126 Mbps. The above is the insufficient Internet coverage in Colombia, particularly in rural areas and non-capital cities. An interesting aspect manifested was the possibility of making a remote connection with the University servers to develop online practices using specialized software.

Q4 - What additional technological conditions consider required to perform the learning process from home?

Mobile devices with suitable data plans for remote interaction, computers with technical characteristics that allow the good use of specialized programs, simulation programs to achieve an approximation, without replacing it, to the experimental component of the subjects that by their design and content require laboratory practice. Tablets with pencils to interact with classmates and teachers during virtual sessions. The use of Moodle ©, Google Drive ©, to unify information in these spaces. Financing.

Q5 - What perception has been generated, the way the teachers have approached the teaching processes in non-face-to-face mode? Cite methodologies.

Some teachers were very strict at the beginning of the process and did not accept consent. It was stated that it was a learning process for everyone (teachers, students) since the transition to a non-face-to-face modality was abrupt, and the University in its conception is face-to-face, so there was no prior preparation that would allow addressing the virtuality.

A group of professors continued, mainly at the beginning of the pandemic and confidence, with a methodology of a master class through the Internet. Based on the responses provided, this perception was typified as follows:

- Teachers who did not interact with their students in the remote mode
- Teachers who continued with face-to-face methodologies
- Teachers who adopted methods and changes aimed at teaching-learning in a non-face-to-face mode

Q6 - Do you consider that the subject, according to its typology, can be developed in a non-face-to-face mode?

The students answered that if it was possible to develop a course as a Metalworking Process Workshop in a non-face-to-face mode, autonomous learning is an important element and even more active participation by the teacher. However, the fact of not being able to carry out the practical part of laboratories is regretted, which due to their typology require presence. In this regard, they expressed the possibility of using videos of activities related to laboratories to achieve an approach that, without being a substitute, would allow them to understand the experimental phase better. They also expressed that specialized software and simulators would enable a path to the practical component, with monitoring sessions to clarify doubts.

Q7 - Consider that it is possible to develop learning processes based on problem-solving in person and or non-face-to-face?

The students answered that it is possible to develop problem-based learning in a non-face-to-face mode, which was achieved during the 202-01 semester. They showed how this methodology allowed them to visualize the theory in practical applications by developing a proposal to manufacture an object based on the content of the course. They highlighted the importance of autonomous learning, the inquiry and research required to advance on the solution of the manufacturing problem and appropriating the applicability of knowledge in situations that they may face in their future professional practice. They consider important the use of the resources available on the Internet, as well as the manufacturing experience of the teacher, their ability to transmit this knowledge, and their availability to carry out consultancies and feedback processes. They also indicated the relevance of collaborative work for the development of advances and formulation of solution proposals. They suggest doing more planning and doing more exercises related to specific topics. The PBL allows them to face real manufacturing situations

Q8 - What resources consider it necessary to develop a problem-based learning process in a non-face-to-face education modality?

Specialized software such as AutoCad ©, Solid Edge ©, Inventor ©, Flexim ©; in addition to the Office suite, especially Word ©, Excel ©, PowerPoint ©. They highlight the importance of implementing the use of manufacturing-specific simulation software. Regarding this aspect, there are simulators such as CNCSimulator Pro © (In demo version, due to its license cost) and free access such as those from Fagor Automation. Also, databases or repositories where coursework from previous semesters is located for specific queries since much of this content is specific and cannot be found on the Internet.

They state that teamwork should be privileged, and meetings are not developed just to comply, although other students indicate how collaborative work allowed them to face problems as a challenge and seek solutions to demonstrate their ability concerning learning in manufacturing.

Q9 - How do you think the development of the curriculum has been affected by the confinement associated with COVID 19?

The students stated that the curriculum was established and designed for a context other than virtual and distance training. As the National University of Colombia is an institution of face-to-face education, various situations arose. A transition period characterized by adaptation to virtuality for the development of courses with improvisation, a process accelerated by the desire to comply with an academic program established before the declaration of a pandemic in a face-to-face situation, the impossibility of carrying out laboratories, experimentation, and practical components, the condensation of content with an excessive assignment of work, made for many teachers it was not easy to adapt the curriculum and others had not been able to do so. It was stated that there were students who passed subjects without having acquired the knowledge, delays in the courses, among others. For some students, teamwork was difficult, and they met more to accomplish than to learn.

On the other hand, they also stated that the University implemented policies to correct these situations.

Q10 - What has been the impact on evaluation processes?

One of the platforms used the most for conducting evaluations was Moodle ©. Some aspects criticized around this platform were the assigned evaluation times and the impossibility of giving related opinions since there are many closed questions. Other students indicated that teachers substituted many evaluations for assignments, projects, exercises, and discussions. Other teachers continued with the assessment as it was carried out in person, and others sent the questionnaires to the email or a link. If the student could not access it, they had no opportunity to respond, and the teacher assumed a radical attitude about it, making it impossible for the student to fulfill the commitment.

The students indicated the difficulty that, in the non-face-to-face modality, is presented for the control of the evaluations. They stated that copying is easy, and one of the mechanisms they use is the creation of groups in WhatsApp ©, in which they distribute and share the resolution of the evaluations or develop them jointly, in addition to having all the notes of class. Books, among others, as support material.

An interesting comment is the number of topics that should be addressed for each evaluation. Unfortunately, this volume of study topics meant that much of them were not considered, and the process became somewhat random concerning the questions that were asked. As a result, for another student, academic performance dropped.

Con el siguiente análisis, se buscó dar respuesta a las preguntas de investigación RQ1 (How has the students' learning process been affected by the transition from a face-to-face environment to a non-face-to-face one?) y RQ2 (- What factors have affected students' interest in knowledge acquisition and capacity building with the non-face-to-face learning modality?). A first impact generated in the academic community of the National University of Colombia by the disruptive change in the teaching processes towards a non-face-to-face modality, due to COVID19, is the fact that no one was prepared for this situation. As it had a structure associated with face-to-face training, the university did not have a suitable curricular structure for face-to-

face training. As a result, the teaching methodologies, study plans, forms of evaluation, didactic strategies, training, and pedagogical processes of the teachers in non-face-to-face modality, necessary training processes, and other aspects were designed and implemented for the present situation that continues to date.

In particular, the impact on students was manifested fundamentally in the interaction processes with their classmates, teachers, and course contents. The axis on which the non-face activity is based is related to the required communication channel. This requires connectivity through the Internet between the different protagonists of the process, for which the country's installed infrastructure is vital. Another element to consider in this communication process is the interfaces that allow the interaction between senders and receivers of the communication process. In this way, computers should ideally be used as basic primary communication terminals. This does not mean that other types of technology, such as tablets and mobile devices, cannot be used — the latter with good data plans and adequate transmission capacity to the navigation requirements in a teaching-learning environment.

Although these are the expected conditions, the reality that the students faced was different. Students have other technologies such as laptops or desktops, cellular communication devices, and tablets. However, the capacity (configuration) and technical specifications, particularly the computers, were not the most adequate for developing learning processes in a non-face-to-face mode. Evidence of the above was the impossibility of adequately using specialized software and simulation programs required for the development of some subjects, as these applications were not able to be used, or in a bad way due to the low processing capacity of the computers. Sometimes students had to connect to the class session using their mobile devices. Although they could establish communication, this type of technology, due to its hardware limitations, did not allow them to interact beyond the simple fact of pure emission and reception, leaving them without the possibility of using software and simulation programs acceptably. The same occurred with the use of tablets, given their technical limitations. In addition, some students only had their cellular devices and did not have adequate internet or data plans. To alleviate this situation, the University established a program to help these students consisting of the supply of tablets and the financing of data plans, which has remedied the communication problem in a certain way.

On the other hand, aspects such as the quality and capacity of the Internet, its latency and intermittency, were some situations that did not allow adequate learning activities in the absence of presence. A problem that increased a deficient use of the Internet was caused because many of the members of the family nucleus of the students had to do remote work and remote education, many times simultaneously. For this reason, they had to make financial investments to solve this problem by contracting plans for greater navigation capacity. Even so, failures continued. In addition to the above, not all country regions have Internet, or the supply of this service is deficient. This situation is evidenced with greater intensity in rural areas and small municipalities far from large urban centers of influence.

The process was affected also, by drops in the electricity supply, which canceled the functionality of this entire system (network, computers, mobile devices, tablets) and sometimes impeded communication and interaction with the users. teaching-learning processes that were in development. (Not controllable).

Another aspect that impacted the students was how the teachers approached the teaching-learning processes in a non-face-to-face mode. Regarding this aspect, it can be said that different situations arose within which the following could be highlighted:

- Teachers who continued with their teaching activity without modification of the methodologies used in face-to-face mode

- Teachers who faced the situation, and from the beginning of the pandemic and not being present, sought to adapt their methodologies to the specific situation

- Teachers who did not hold virtual sessions and limited themselves to interacting through emails.

- Teachers who already had experience related to activities with the use of ICTs

The adaptation to non-presence was abrupt, eager, and highly improvised, which did not allow adequate interaction. First, due to the impossibility or low capacity of some teachers to communicate using ICTs; second, because despite the fact that many teachers tried to carry out self-taught training about tools for virtuality, this demanded time and effort related to the investigation, internalization, and implementation of the different mechanisms that allowed communication in non-contact environments. A third aspect is related to situations in which some teachers acted in an authoritarian manner and did not admit the reasons that students argued for the impossibility of having connected to a session, not being able to present a workshop, or not being able to attend an evaluation, due to technical failures, such as those mentioned above. Another aspect is related to the fact that some teachers did not privilege the dialogue to the point that the interaction was limited to sending guides and evaluation schedules without interaction in a non-face-to-face mode, beyond the use of email and the citation to evaluations on predetermined dates.

However, the students recognize the effort made by most teachers to develop the subjects and the achievement of the learning objectives by changing their methodologies and appropriating the use of ICT over time.

The preceding is related to the fact that, since the University was an institution with a face-to-face training nature, it had not carried out training processes to develop distance education processes. For this reason, the teachers did not have the knowledge associated with managing

An important impact expressed by the students is related to the possibility of taking the courses in a non-face-to-face mode. In general terms, the situation is summarized in two groups: A first group comprises subjects that do not include experimental or laboratory activities and face-to-face practices in industrial or service organizations. For this type of subject, it is considered that doing them non-face-to-face does not present any difficulty. A second group comprises subjects with an experimental component, laboratory experimentation, or industrial or service organizations practices. It was possible to develop the theoretical part for these groups, but not the experimental and practical component. The absence of both experimental or practical components generated a void in the students with applying and validating the theoretical knowledge. They suggested using simulators and related practice videos, but the scope is limited and did not meet the expected knowledge expectations.

The same void manifested above was generated concerning the possibility of applying the problem-based learning methodology in a non-face-to-face mode. However, there was a positive impact with the use of the PBL, since the students stated that they managed to integrate the theory with its practical application through the solution of a manufacturing problem related to real situations at the industrial level, for the case of the Metalworking Process Workshop course. They suggested using simulators to observe and understand the transformation processes, virtual reality glasses, databases with antecedents of previous experiences in which the same methodology was used for specialized consultations, and having the professor's skills at an industrial level, such as complement to the learning process.

Curriculum and assessment topics were circumstantial for the students. The most expressed and impacted the students were improvised, increased work, condensation of content, and inappropriate teaching methodologies. Regarding the evaluation, the students were affected because many of the classmates resorted to copying without considering the effects this practice could generate. As a result, they were unable to visualize a form of evaluation that would truly demonstrate the level of knowledge acquired and its quality.

De esta manera, los resultados anteriores se pueden relacionar con la Hipótesis 1 (H1- The implementation of changes at the curriculum level (teaching methods, adjustments in the course program, comprehensive training), pedagogical (forms of evaluation, didactic) allow to develop of the methodology of learning based

on problems in a modality of non-face-to-face teaching and favor autonomous learning, collaborative learning and social building of knowledge).

4.2 Surveys

The four surveys that were implemented through Google Forms have been piloted during the 2020-01 semester. A file with the results has been generated.

- Perception Questionnaire on Autonomous Learning and Collaborative Learning (Integrated)

Global participation: 27 students (38% of students in the two subjects)

Participation Introduction to Industrial Engineering: 13 students (32.5%)

Participation Metalworking Process Workshop: 14 students (46%)

- Learning preferences Questionnaires (Integrated)

Global participation: 20 students (2 8.7%of students in the two subjects)

Participation Introduction to Industrial Engineering: 11 students (27.5%)

Participation Metalworking Process Workshop: 9 students (30%)

During the 2020-02 semester, the surveys related to the same topics (Perception Questionnaire on Autonomous Learning and Collaborative Learning (Integrated) and Learning preferences Questionnaires (Integrated)) were applied to the group of the subject Metalworking Processes Workshop, made up of 27 students. The surveys responded to the specific objectives SO3 and SO4

4.2.1 Perception Questionnaire on Autonomous Learning and Collaborative Learning (Integrated)

The data collected correspond to surveys carried out during the periods 2020-01 and 2020-02, to students of the subjects Metalworking Process Workshop (Fifth semester), Quality Control and Management (Sixth semester) and Introduction to Industrial Engineering (First semester), according to the distribution shown in the contingency table (Table 5)

Count				
		Semester		Total students
		0	1	
Subject taken	Quality Control and Management	0	21	21
	Introduction to Industrial Engineering	13	0	13
	Metalmechanical Process Worshop	14	25	39
Total students		27	46	73

Table 5 Contingency table. Subject taken .vs. Semester (0:2020-01; 1:2020-02) (Source Author´s elaboration)

Period 2020-01:

- Metalworking Process Workshop: 14 students
- Introduction to Industrial Engineering: 13 students

Period 2020-02:

- Metalworking Process Workshop: 25 students
- Quality Control and Management: 21 students

The instrument "Perception Questionnaire on Autonomous Learning and Collaborative Learning" (Appendix 4) was applied, with a total participation of 27 students for the 2020-01 period and 46 students for the 2020-02 period (Table 6).

Consolidated results of these surveys are found in Appendix 7.

	Semester	N	Media	Typical Deviation.	Type 1 Error. Error of the Mean
Studytech/AL	1	46	4,1413	,60243	,08882
	0	27	4,4074	,62075	,11946
Remote CL	1	46	4,0797	,64477	,09507
	0	27	3,9259	,77533	,14921

Table 6 Total participation of students – Descriptive statistics for AL and CL (Taken from SPSS © report)

To validate the use of the totality of data, taken from two different academic periods, and to give greater solidity to the information generated by having the participation of a larger sample of students, an evaluation was carried out using a t-test of difference between means for the two constitutive categories of the survey: autonomous study/learning techniques (Studytech / AL) and collaborative learning in remote mode (Remote CL). In addition, it aims to determine if there was a change in behavior in the students' perceptions between the first and second semesters of 2020. Therefore, in the first group (2020-01), 46 data were included; and in the second group (2020-02), all 27 data were included.

The results obtained when making the difference between means for each category are shown in Table 7.

	Semester	N	Media	Difference between means
Studytech/AL	1(2020-02)	46	4,1413	-0,2661
	0 (2020-01)	27	4,4074	
Remote CL	1(2020-02)	46	4,0797	0,1538
	0(2020-01)	27	3,9259	

Table 7 Group Statistics (Taken from SPSS © report)

It is observed that, for Studytech / AL, the average of the first 27 data is greater for the academic period 2020-02 (4.4074) than for the academic period 2020-01 (4.1413) with 46 data, and their difference it is negative and significant; that is, it would allow us to presume that the perception regarding this category did not change. In the case of Remote CL, the mean values are very close (2020-02 [27 data]: 3,9259 .vs. 2020-01 [46 data]: 4,0797) and although their difference is positive, it does not is conclusive.

Due to the results obtained, an inferential hypothesis test was performed for the two categories. The results are shown in Table 8.

Independent samples test

		Levene's test for equality of variances	
		F	Sig.
Studytech /AL	Equal variances have been assumed	,338	,563
	Equal variances have not been assumed		
Remote CL	Equal variances have been assumed	1,707	,196
	Equal variances have not been assumed		

Table 8 Inferential hypothesis test for the two categories (Taken from SPSS © report)

Table 8 shows the results of Levene's test for equality of variances, and it is observed that the hypothesis that the variances are equal for any of the two variables cannot be rejected.

Independent Samples Test

		T test for equality of means			
		t	gl	Sig. (bilateral)	Difference between means
Studytech/ AL	Equal variances have been assumed	-1,802	71	,076	-,26610
	Equal variances have not been assumed	-1,788	53,284	,080	-,26610
Remote CL	Equal variances have been assumed	,912	71	,365	,15378
	Equal variances have not been assumed	,869	46,925	,389	,15378

Table 9 Independent Samples Test for equality of means. (Taken from SPSS © report)

According to the data observed in Table 9, it was found, for a decision level for the hypothesis test of $\alpha = 0.05$, a significance of 0.076 (7.6%) for category 1 and 0.365 (36.5%) for category 2. This result validated that the hypothesis that the means are equal could not be rejected, which allowed us to conclude that there was no behavioral change in the perceptions of the former versus the former in second semester of 2020. Based on the above, the use of all the data collected in 2020 was validated with a sample of 76 students.

Initially, the data corresponding to the 11 variables related to autonomous and collaborative learning was processed, based on the set of questions with a 5-point Likert scale of the instrument (Appendix 4). When observing the content of the 11 constituent items of the survey, put into consideration to students, dimensions or categories referring to similar aspects are perceived.

Based on the above, the results will be reported, not in terms of the 11 variables separately, but synthesized in the minimum analytically possible units. The technique used for this synthesis was Principal Component Analysis, also known as Exploratory Factor Analysis. Employing this technique, with the use of covariance matrices between what people answered to each of these questions and with orthogonality processes, the internal correlation was maximized, and the extremes were sought, which allowed the establishment of factors or categories that could be differentiated from each other, but within which similar aspects were grouped that are related to each other, as they are part of the same conceptual construction.

In the first cycle of analysis, the 11 variables were entered, which were reported by the SPSS © software, at the beginning of the factorial analysis, as seen in Figure 11.

```
FACTOR
  /VARIABLES @1.1 @1.2 @1.3 @1.4 @1.5 @1.6 @1.7 @1.8 @1.9 @1.10 @1.11
  /MISSING LISTWISE
  /ANALYSIS @1.1 @1.2 @1.3 @1.4 @1.5 @1.6 @1.7 @1.8 @1.9 @1.10 @1.11
  /PRINT INITIAL KMO AIC EXTRACTION ROTATION
  /FORMAT SORT
  /CRITERIA MINEIGEN(1) ITERATE(25)
  /EXTRACTION PC
  /CRITERIA ITERATE(25)
  /ROTATION VARIMAX
  /METHOD=CORRELATION.
```

Figure 11 Factor analysis - first round (Taken from SPSS © report)

The technique allowed, from the report of a set of coefficients obtained through the Kaiser-Meyer-Olkin adequacy measure and the Bartlett sphericity test (Table 10), to form groups or categories of variables with high correlation. For this, several rounds were conducted. The coefficients obtained from the Kaiser-Meyer-Olkin adequacy measure and Bartlett's sphericity test in the first round are shown in Table 10; and in Table 11, the corresponding anti-image matrices.

Kaiser-Meyer-Olkin sample adequacy mean		,757
Bartlett's test of sphericity	Approximate Chi-square	254,330
	gl	55
	Sig.	,000

Table 10 KMO results and Bartlett's test, first round (Taken from SPSS ©)

		1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	1.10	1.11
Anti-image covariance	1.1	,681	,017	,009	-,058	-,155	-,049	-,026	-,037	-,049	-,117	,055
	1.2	,017	,509	-,097	-,067	-,137	,029	-,109	,081	-,103	-,016	-,065
	1.3	,009	-,097	,541	-,190	-,006	-,136	,097	,034	,084	,029	-,034
	1.4	-,058	-,067	-,190	,345	-,145	,156	-,072	-,011	-,052	-,029	-,066
	1.5	-,155	-,137	-,006	-,145	,422	-,081	,020	,063	,018	-,021	,001
	1.6	-,049	,029	-,136	,156	-,081	,727	-,131	-,061	-,046	-,180	-,047
	1.7	-,026	-,109	,097	-,072	,020	-,131	,860	-,067	-,042	,008	,056
	1.8	-,037	,081	,034	-,011	,063	-,061	-,067	,452	-,160	-,063	-,277
	1.9	-,049	-,103	,084	-,052	,018	-,046	-,042	-,160	,707	-,088	,020
	1.10	-,117	-,016	,029	-,029	-,021	-,180	,008	-,063	-,088	,697	-,048
	1.11	,055	-,065	-,034	-,066	,001	-,047	,056	-,277	,020	-,048	,492
Anti-image correlation	1.1	,846[a]	,028	,016	-,120	-,289	-,069	-,034	-,067	-,070	-,170	,095
	1.2	,028	,834[a]	-,184	-,161	-,295	,048	-,164	,168	-,172	-,027	-,129
	1.3	,016	-,184	,756[a]	-,438	-,013	-,216	,142	,070	,135	,048	-,067
	1.4	-,120	-,161	-,438	,753[a]	-,380	,312	-,131	-,028	-,105	-,060	-,159
	1.5	-,289	-,295	-,013	-,380	,798[a]	-,145	,033	,144	,033	-,039	,002
	1.6	-,069	,048	-,216	,312	-,145	,599[a]	-,166	-,106	-,064	-,252	-,078
	1.7	-,034	-,164	,142	-,131	,033	-,166	,716[a]	-,107	-,054	,010	,086
	1.8	-,067	,168	,070	-,028	,144	-,106	-,107	,622[a]	-,284	-,113	-,589
	1.9	-,070	-,172	,135	-,105	,033	-,064	-,054	-,284	,802[a]	-,126	,033
	1.10	-,170	-,027	,048	-,060	-,039	-,252	,010	-,113	-,126	,855[a]	-,082
	1.11	,095	-,129	-,067	-,159	,002	-,078	,086	-,589	,033	-,082	,693[a]

Table 11 Results of anti-image matrices, first round (Source: SPSS © report)

Based on the values found on the diagonal (values with superscript a - red line of the anti-image correlation - Table 11) or based on the communalities (for the first round) indicated in Table 12, it was decided which variables (items) to extract and which to keep based on the form of organization between them.

	Initial	Extraction
1.1	1,000	,500
1.2	1,000	,639
1.3	1,000	,620
1.4	1,000	,792
1.5	1,000	,731
1.6	1,000	,461
1.7	1,000	,437
1.8	1,000	,802
1.9	1,000	,434
1.10	1,000	,497
1.11	1,000	,795

Table 12 Communalities (Excerpted from SPSS report ©)

For the particular study, related to the survey, after five rounds based on the results obtained by SPSS ©, the data were decanted, since in the KMO test the value obtained was greater than 0.7 (Table 9); in the anti-image matrix (Table 11) the values of the diagonal with superscript a were higher than 0.6 (it is established that they must be ≥ 0.6) and for the case of communalities (Table 12) the values were higher or equal to 0.5 (≥ 0.5). This led to the extraction of variables 1, 6, 7 and 8 (Table 13).

Variable N°	Description
1 (ST/AL)	Autonomous learning is a fundamental component in the processes of acquiring knowledge and for the development of competencies and skills.
6 (AL)	Autonomous learning should be a process capable of receiving feedback
7 (ST/AL)	Hetero-evaluation and self-evaluation of the study techniques used can be considered mechanisms to develop the feedback of autonomous learning. (Hetero-evaluation: Evaluation carried out by one person of the activities and processes designed by another person - Self-evaluation: Evaluation developed by the student himself based on principles such as honesty; and with the capacity for self-criticism and will to improve)
8 (CL)	Collaborative learning is important for teaching-learning processes since it allows all community members to participate in small groups in the search for the solution to a problem and the achievement of learning objectives.

Table 13 Extracted variables (Source: Author´s elaboration)

Table 14 shows the variables that were conserved for the study:

Variable N°	Description
2 (ST/AL)	Study techniques are an important didactic mechanism, which facilitates the learning process and the study of specific topics.
3 (ST/AL)	For the development of autonomous learning processes, the use of study techniques is important
4 (ST/AL)	The use of study techniques as an instrument that contributes to autonomous learning allows increasing academic performance

5 (ST/AL)	Using study techniques as an instrument that contributes to autonomous learning makes it possible to improve the understanding of specific topics.
9 (CL)	Collaborative learning, as a strategy based on teamwork, can be developed in a remote mode.
10 (CL)	Activities related to collaborative learning can be developed in online sessions to create tutorials and support.
11 (CL)	It is important to have a space for the development of teamwork activities online.

Table 14 Variables retained for the study. (Source: Author´s elaboration)

Figure 12 shows, from SPSS ©, the variables that remained under investigation (2, 3, 4, 5, 9, 10, 11)

```
FACTOR
  /VARIABLES @1.2 @1.3 @1.4 @1.5 @1.9 @1.10 @1.11
  /MISSING LISTWISE
  /ANALYSIS @1.2 @1.3 @1.4 @1.5 @1.9 @1.10 @1.11
  /PRINT INITIAL KMO AIC EXTRACTION ROTATION
  /FORMAT SORT BLANK(.40)
  /CRITERIA MINEIGEN(1) ITERATE(25)
  /EXTRACTION PC
  /CRITERIA ITERATE(25)
  /ROTATION VARIMAX
  /METHOD=CORRELATION.
```

Figure 12 Variables that remained under study (Taken from SPSS ©)

Table 15 shows the coefficients obtained from the Kaiser-Meyer-Olkin adequacy measure and Bartlett's sphericity test, for the fifth round; and in Table 16 the corresponding anti-image matrices. The communalities are shown in Table 17.

Kaiser-Meyer-Olkin sample adequacy mean		,788
Bartlett's test of sphericity	Approximate Chi-square	150,686
	gl	21
	Sig.	,000

Table 15 KMO sample adequacy measure. Value> 0.7 (Fifth round) (Taken from SPSS ©)

		1.2	1.3	1.4	1.5	1.9	1.10	1.11
Anti-image covariance	1.2	,537	-,098	-,092	-,165	-,091	,008	-,019
	1.3	-,098	,577	-,188	-,029	,110	,006	-,048
	1.4	-,092	-,188	,390	-,179	-,065	-,004	-,094
	1.5	-,165	-,029	-,179	,481	,024	-,081	,067
	1.9	-,091	,110	-,065	,024	,796	-,189	-,150
	1.10	,008	,006	-,004	-,081	-,189	,798	-,188
	1.11	,019	-,048	-,094	,067	-,150	-,188	,779
Anti-image correlation	1.2	,849[a]	-,177	-,200	-,325	-,140	,012	-,029
	1.3	-,177	,805[a]	-,396	-,056	,162	,008	-,072
	1.4	-,200	-,396	,774[a]	-,412	-,116	-,006	-,170
	1.5	-,325	-,056	-,412	,787[a]	-,038	-,131	,109
	1.9	-,140	,162	-,116	-,038	,699[a]	-,237	-,191
	1.10	,012	,008	-,006	-,131	-,237	,757[a]	-,239
	1.11	-,029	-,072	-,170	,109	-,191	-,239	,764[a]

Table 16 Anti-image matrix- Diagonal values with superscript a greater than 0,6 (Fifth round) (Taken from SPSS ©)

	Initial	Extraction
1.2	1,000	,654
1.3	1,000	,636
1.4	1,000	,775
1.5	1,000	,688
1.9	1,000	,586
1.10	1,000	,565
1.11	1,000	,516

Table 17 Communalities. Extracted values greater than 0.5 (Fifth round) (Taken from SPSS ©)

As the mentioned indices were adequate, a two-component structure was established (Columns 1 and 2 - Table 18). Component 1, made up of variables 2, 3, 4 and 5 (Table 18) related to study techniques and autonomous learning; and component 2 (Variables 9, 10, and 11 - Table 18) related to collaborative learning.

Component 1 explains 44.18% of the variance of all the data and component 2 explains 18.96%. The first component is very strong and the second is less so. There is a cumulative that explains more than 2/3 parts; that is to say, greater than 63%. In Social Sciences, 60% or more is a good measure. In this way, with the indicated 2-component structure, more than 60% of the variability of all the data obtained in the surveys is being explained. Table 16 shows the result after performing the orthogonality with the Rotation method by normalization of Varimax with Kaiser.

	Component	
	1	2
1.4	,848	
1.5	,819	
1.3	,797	
1.2	,785	
1.9		,763
1.10		,742
1.11		,693

Table 18 Rotated component matrix (Extraction method: Principal component analysis. Rotation method: Varimax normalization with Kaiser).) (Taken from SPSS ©)

The values indicated in columns 1 and 2 (Table 18) for the two components are called factorial loads (Loudings). It is recommended that its value be ≥ 0.7 to correspond with the Average Variance Extracted (AVE) or average extracted variance. The AVE was calculated as the average of the sum of the squares of each of the indicated values. The results were compared with the established one (≥ 0.5) based on factor loadings. The AVE for component 1 was 0.6603 and for component 2 it was 0.5376.

Subsequently, the reliability was evaluated, for which each category was selected separately, and the Cronbach's Alpha Index was calculated, to determine the stability of the results if the exercise were repeated. (Figure 13)

```
RELIABILITY
  /VARIABLES=@1.10 @1.11 @1.9
  /SCALE ('ALL VARIABLES') ALL
  /MODEL=ALPHA
  /SUMMARY=TOTAL.
```

Figure 13 Reliability evaluated for each category separately) (Taken from SPSS ©)

For the first block of the first category, a Cronbach's Alpha of 0.84 was obtained for the 4 variables (Table 19).

Cronbach's Alpha	N° of elements
,840	4

Table 19 Cronbach's Alpha for Category 1(Taken from SPSS ©)

This value is considered adequate since it must be ≥ 0.7. To validate the results, one of the variables was withdrawn at a time, and on all occasions Cronbach's alpha decreased (Table 20). The foregoing indicates that none of them could be excluded, which is why they were maintained. In this way, based on the SPSS © reports, this category was validated (which explains 44% of all the variance of the data structure) with high Cronbach's Alpha values, which gave it a very strong value.

	Mean of scale if item is removed	Variance of the scale if item is removed	Corrected item-total correlation	Cronbach's alpha if item is removed
1.2	12,53	4,141	,666	,809
1.3	12,70	3,908	,613	,822
1.4	12,82	3,148	,763	,755
1.5	12,82	3,315	,689	,793

Table 20 Cronbach's alpha variation first category (Variables 2, 3, 4, 5). (Taken from SPSS ©)

From the point of view of the variables contained in this category, which correspond to items related to Study Techniques and Autonomous Learning, the importance that students give to aspects such as (1.2), (1.3), (1.4) and (1.5) is observed.

Cronbach's Alpha	N° of elements
,599	3

Table 21 Cronbach's Alpha for Category 2) (Taken from SPSS ©)

The reliability of the second category (Factor) (Table 21) is lower, with a value of 0.6 less than 0.7; and includes about 20% of the data. Although it is considered low, it can be assumed with caution as it is minimally acceptable. On the other hand, the validation of results, when removing each one of the variables at the same time, yielded lower values of Cronbach's Alpha (Table 22). As in category 1, it indicates that none of the variables can be excluded, which is why the structure was also maintained and was maintained.

	Mean of scale if item is removed	Variance of the scale if item is removed	Corrected item-total correlation	Cronbach's alpha if item is removed
1.10	8,04	2,262	,421	,478
1.11	7,86	2,231	,403	,506
1.9	8,23	2,459	,400	,510

Table 22 Cronbach's alpha variation first category (Variables 9. 10,11). (Taken from SPSS ©)

All of the above was reduced to two measures: the average of the first 4 variables corresponding to study techniques and autonomous learning (ST / AL); and the average of the other 3 variables corresponding to collaborative learning (CL) in non-face-to-face mode.

	N	Minimum	Maximum	Media	Typical dev
Studytech	73	2,00	5,00	4,2397	,61863
Remote	73	2,00	5,00	4,0228	,69462
Valid N (according to list)	73				

Table 23 Descriptive statistics (Rows 1 (ST / AL) and 2 (CL)) calculated by SPSS ©.) (Taken from SPSS ©)

Table 23 shows the descriptive statistics (Rows 1 (ST / AL) and 2 (CL)) calculated by SPSS © for these two measures, which are related to the established Lickert scale. It is observed that the mean for ST / AL (Variables 2, 3, 4, 5 Table 14), is 4.23 with a standard deviation of 0.61863; for CL (Variables 9, 10,11 Table 14) the mean is 4.02 with a standard deviation of 0.69462

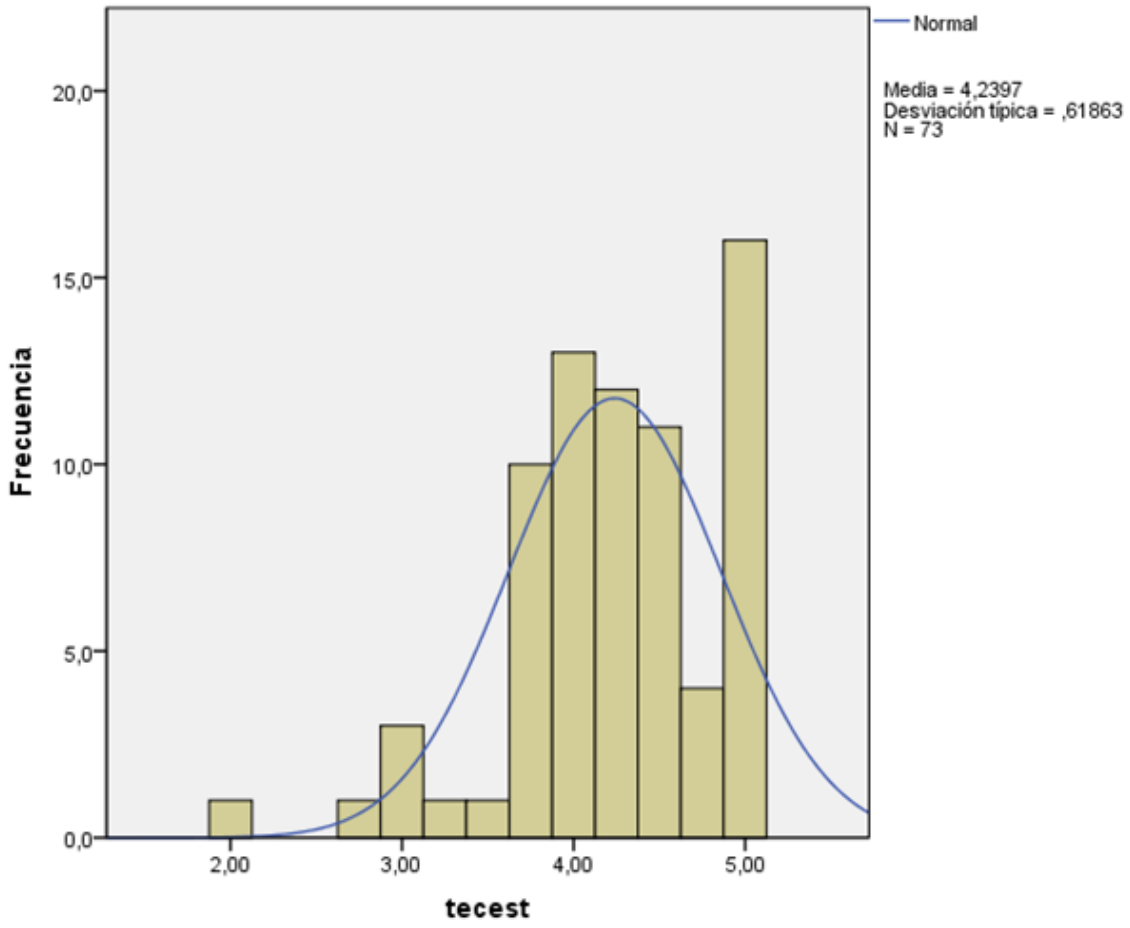
The Likert scale for the established propositions, with the objective of knowing the perception of the students in relation to ST / AL and CL was the following (Table 24):

LIKERT SCALE		AVERAGE CATEGORY 1
Scale value	Descriptor	
1	Total disagreement	
2	Disagreement	
3	Indifferent	
4	Partially agree	4,2397
5	Totally agree	

Table 24 Likert scale for established propositions (Source: Author´s elaboration)

In this way, the perception of students in relation to ST / AL, in addition to being a reliable result, tends to be more towards totally agree (5) than partially agree (4), for the selected variables, validating the importance of implementing and promoting non-face-to-face learning processes (learning, a structure based on ICTs oriented to collaborative work and the use of study techniques associated with this form of work and autonomous learning. A complementary study, to affirm the previous validation, was carried out

from descriptive statistics. Figure 14 shows the histogram associated with the descriptive statistics of



ST/AL.

Figure 14 Histogram associated with the descriptive statistics of ST / AL (Taken from SPSS ©)

The blue curve is the one that SPSS © imposes if a normality assumption were fulfilled. A high tendency of weighting is observed by the students, in relation to the Likert scale, to perceptions of partially agree, to agree totally. The distribution obtained has a bias towards the right and approximately 12 values of 73 are outside the range imposed by the normal curve. Thus, although the assumption of normality of the data is not fulfilled, the behavior imposes a vision towards a significant preference in relation to ST / AL.

The distribution curve corresponding to remote learning (Figure 15) is closer to a normal distribution. A higher concentration is observed around the mean (4 and lower than the previous case), and an excess of cases above the expected value is not observed. This is related to a larger standard deviation (0.69462), with more data at the extremes separated from the mean. This suggests that students have more differentiated perceptions for the CL, than in the previous case (ST / AL), in which it is more concentrated towards perceptions tending to be in complete agreement. For this second category, a non-negligible group of students, established a perception of partially in agreement (4.02 in the mean, lower than the previous case) more oriented to the right.

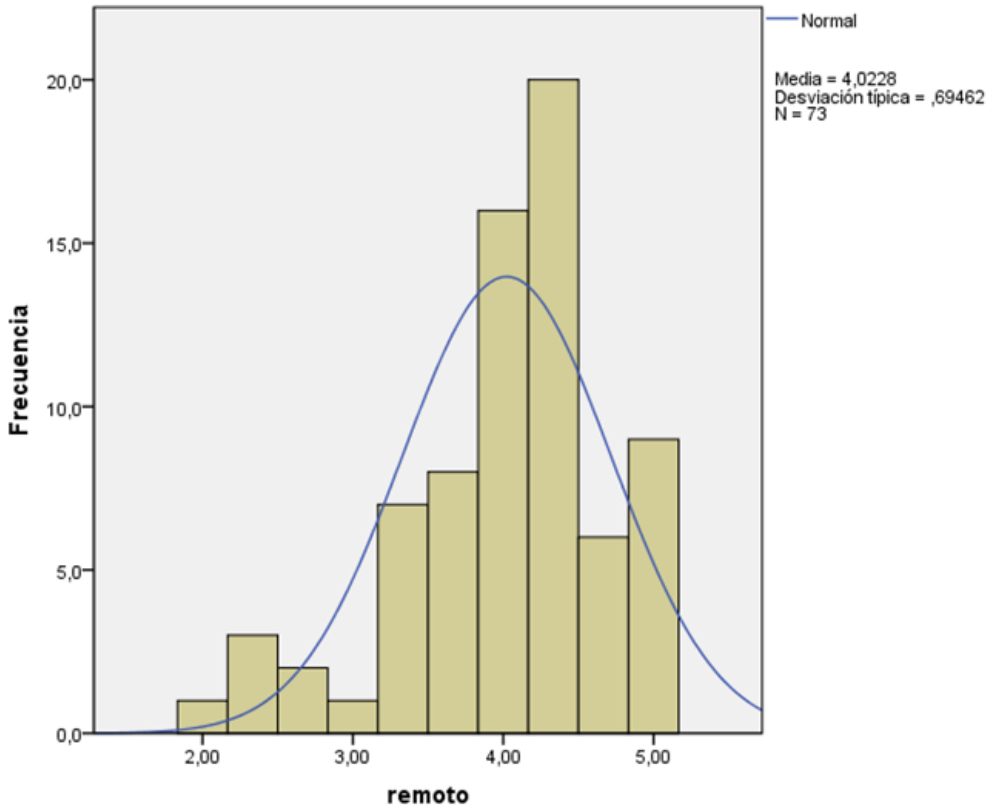


Figure 15 Histogram associated with the descriptive statistics of remote learning (Taken from SPSS ©)

It was sought to establish whether statistically the averages were different from each other, and to inquire about the possible relationship between the two categories. That is, the possibility that the perception of students regarding study techniques and autonomous learning (ST / AL) will show some relationship on the perception of collaborative learning in remote mode (CL).

Correlations			
		Studytech	Remote
Studytech	Pearson's correlation	1	,335**
	Sig. (bilateral)		,004
	N	73	73
Remote	Pearson's correlation	,335**	1
	Sig. (bilateral)	,004	
	N	73	73
**. The correlation is significant at the 0.01 level (bilateral).			

Table 25 Pearson correlation test to establish whether statistically the averages were different from each other (Taken from SPSS ©)

For this evaluation, based on the nature of the data, a Pearson correlation test was performed (Table 25), which yielded a result of 0.0335. This value, being different from zero and despite tending to be low, is statistically significant at 1%. Thus, it is evident that there is a minimal tendency of, if one category is positive, the other category also.

Once the validity of the results has been established, from the statistical point of view, it is observed how the students conferred for the variables under study, associated with study techniques and autonomous and collaborative learning, an importance between partially and totally in agreement. With regard to autonomous learning, an added importance was given to the use of study techniques as a didactic mechanism that facilitates this learning process, the improvement of academic performance and the understanding and appropriation of specific knowledge. The above, complemented with collaborative learning and teamwork. In addition, a coherence is observed between the results of this survey and those of the semi-structured interview, regarding the development of activities remotely.

The second part of the survey sought to establish the study techniques that students favor for the development of autonomous learning processes. The consolidated results can be found in Appendix 8.

Figure 16 shows the final consolidated result of the data obtained from the opinions of the students.

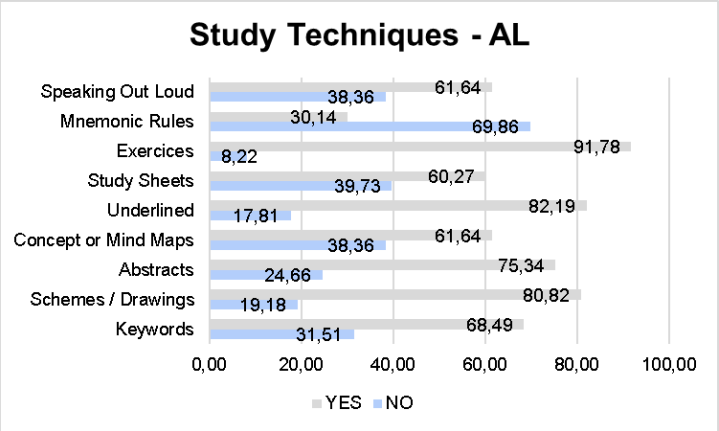


Figure 16 Study Techniques in Autonomous Learning (Source: Author´s elaboration)

In the most favorable extremes, a preference is observed for carrying out exercises related to the subject of the course, which could be associated with the type of technical training on which industrial engineering is based. On the contrary, the use of mnemonic rules is the least used as a study technique. Techniques such as underlining (82.10%) and the use of diagrams and drawings (80.82%) are also privileged. Likewise, a significant percentage of the completion of summaries (75.34%)

A third part of the survey was related to the perception of the students in relation to collaborative learning. For this, 12 different selection options were proposed, the results of which are consolidated in Appendix 8 and are shown in Figure 17.

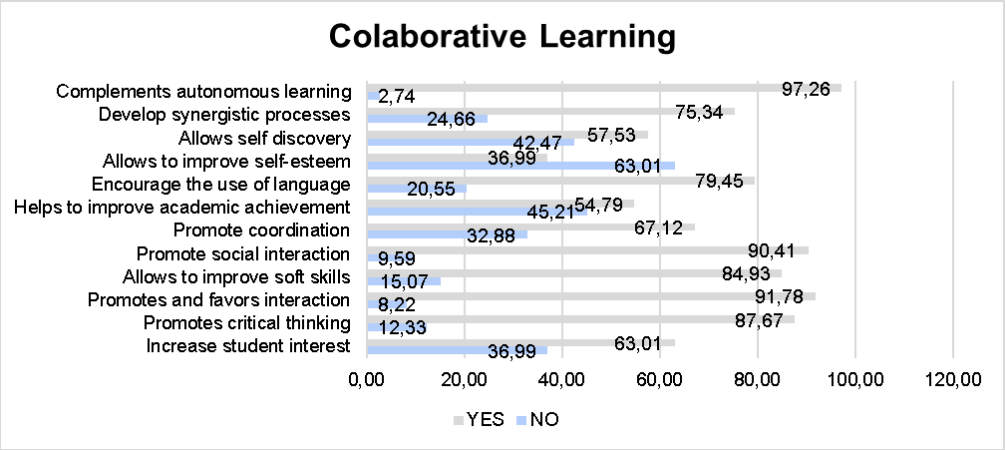


Figure 17 Students' perception concerning collaborative learning (Source: Author´s elaboration)

A very strong perception is observed concerning the vision of collaborative learning as a complement to autonomous learning (97.26%) and important precepts to aspects such as the promotion of interaction (91.78%), the development of critical thinking (87.67%), and improvement of soft skills (84.93%). Other important factors are the use of language (79.45%) and the development of synergistic processes (75.35%)

4.2.2 Learning Preferences Questionnaires

The questionnaire integrated two forms of assessment of learning styles: KOLB and VARK. It was applied to the group of students of the subject Metalworking Processes Workshop of the academic period 2020-02. Participation was 92.6% (25 students out of 27).

The data corresponding to the Kolb learning styles form was analyzed independently from those corresponding to the VARK form.

4.2.2.1 KOLB Form

This form was applied as the underlying theory defines learning as “the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience " [68]

This conception is fundamentally relevant for a subject such as Metalworking Process Workshop, in which the formation of criteria from the theoretical understanding of the processes can be achieved effectively from the experience acquired and related to them, from the application practice.

The learning styles inventory (LSI), being made up of 12 questions with four weighting options for each one (1 to 4), allowed to obtain results with a minimum value of 12 (Score 1 for all questions) up to a value maximum of 48 (Grade 4 for all questions). The higher the value achieved, the greater the student's preference for a specific style.

The network graph for the course grade point average is shown in Figure 18

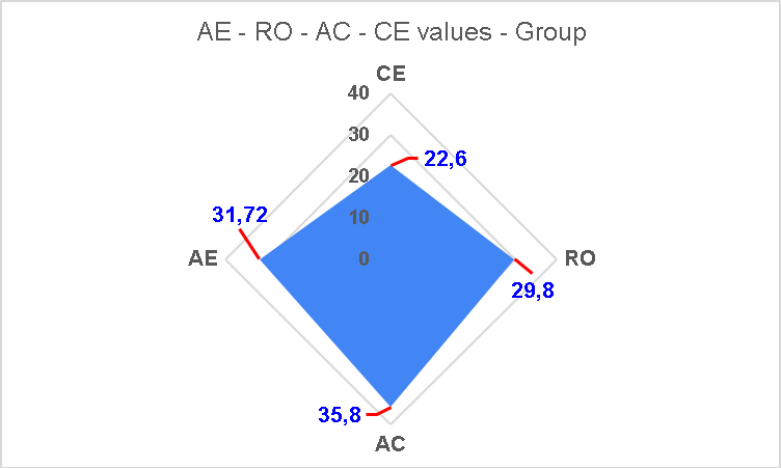


Figure 18 The learning styles inventory – Course average (Source: Author´s elaboration)

The data obtained from the applied KOLB questionnaire are shown in Appendix 9, in Excel © format.

The data analyzed based on Kolb's model involved two main dimensions of learning: perception and processing. These two dimensions in turn integrated the four stages of the learning cycle, established from Kolb's experiential learning style theory (Figure 19), namely:

- Concrete Experience (CE)
- Reflective Observation (RO)
- Abstract Conceptualization (AC)
- Active Experimentation (AE)

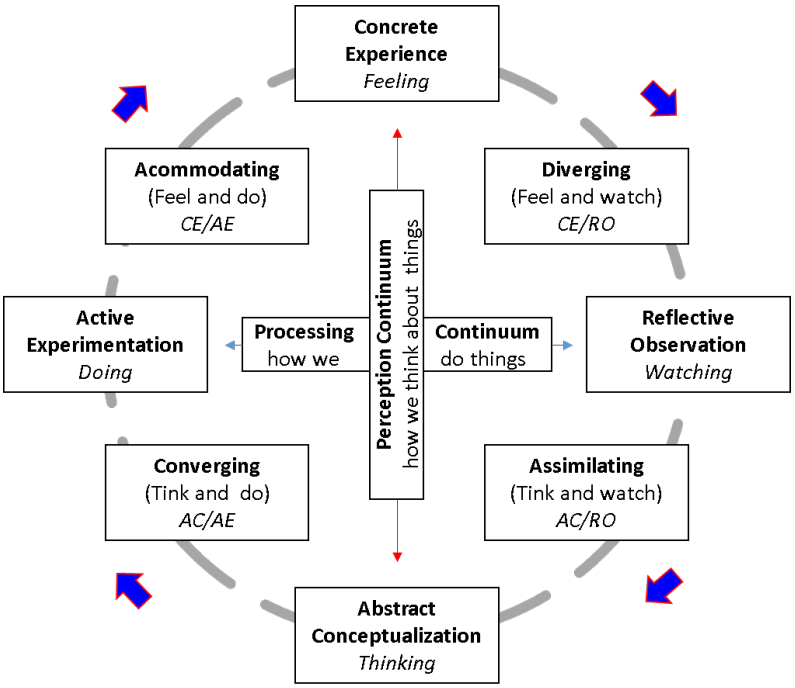


Figure 19 Kolb's model - Main dimensions of learning and stages of the learning cycle (Adapted from [58])

The perception dimension involves how you think about things from a concrete experience (CE) to an abstract conceptualization (AC). The processing dimension, based on how things are done, includes ways of processing from active experimentation (AE) to reflective observation (RO).

To determine the position of each student in the four stages of the learning cycle, the data was totaled as follows (Table 26)

Student	Question (Item)	Column A (CE)	Column B (RO)	Column C (AC)	Column D (AE)
1 to n (students)	1 to 12 for each column				
Total sum per column					

Table 26 Template to determine the position of each student in the four stages of the learning cycle (Adapted from www.victorhugolara.wordpress.com)

Table 27 shows the results of the summations per student and for the entire group:

Student	KOLB COLUMN A SUM (CE)	KOLB COLUMN B SUM (RO)	KOLB COLUMN C SUM (AC)	KOLB COLUMN D SUM (AE)
1	29	20	39	32
2	13	38	43	27
3	16	31	39	33
4	25	22	33	40
5	19	30	40	30
6	21	31	34	33
7	19	35	38	29
8	14	44	35	28
9	19	30	37	35
10	34	27	29	28
11	21	28	28	44
12	21	38	34	27
13	25	30	29	35
14	14	43	37	27
15	34	22	24	40
16	27	34	28	28
17	26	25	28	41
18	22	25	29	46
19	28	25	41	25
20	25	29	39	27
21	18	27	43	34
22	21	24	45	30
23	26	28	45	20
24	22	34	39	27
25	26	25	39	27

Table 27 Sums per student and for the entire group (Source: Author´s elaboration)

Table 28 shows the percentage composition of the results shown in Table 25 and the percentage average of the group.

Student	KOLB Column A (%)	KOLB Column B (%)	KOLB Column C (%)	KOLB Column D (%)
1	24,2	16,7	32,5	26,7
2	10,7	31,4	35,5	22,3
3	13,4	26,1	32,8	27,7
4	20,8	18,3	27,5	33,3
5	16,0	25,2	33,6	25,2
6	17,6	26,1	28,6	27,7
7	15,7	28,9	31,4	24,0
8	11,6	36,4	28,9	23,1
9	15,7	24,8	30,6	28,9
10	28,8	22,9	24,6	23,7
11	17,4	23,1	23,1	36,4
12	17,5	31,7	28,3	22,5
13	21,0	25,2	24,4	29,4
14	11,6	35,5	30,6	22,3
15	28,3	18,3	20,0	33,3
16	23,1	29,1	23,9	23,9
17	21,7	20,8	23,3	34,2
18	18,0	20,5	23,8	37,7
19	23,5	21,0	34,5	21,0
20	20,8	24,2	32,5	22,5
21	14,8	22,1	35,2	27,9
22	17,5	20,0	37,5	25,0
23	21,8	23,5	37,8	16,8
24	18,0	27,9	32,0	22,1
25	22,2	21,4	33,3	23,1
Average (%)	18,9	24,8	29,9	26,4

Table 28 Percentage composition of the results and the average percentage of the group. (Source: Author´s elaboration)

Subsequently, based on Table 29, the X values were calculated: Processing; and Y: Perception, for each student.

Total column D (AE)	minus (-)	Total column B (RO)	=	X: AE - RO (Processing)
Total column C (AC)	minus (-)	Total column A (CE)	=	Y: AC – CE (Perception)

Table 29 X and Y calculus procedure (Adapted from www.victorhugolara.wordpress.com)

The results obtained are shown in Table 30

Student	Processing (X) (AE - RO)	Perception (Y) (AC - CE)
1	12	10
2	-11	30
3	2	23
4	18	8
5	0	21
6	2	13
7	-6	19
8	-16	21
9	5	18
10	1	-5
11	16	7
12	-11	13
13	5	4
14	-16	23
15	18	-10
16	-6	1
17	16	2
18	21	7
19	0	13
20	-2	14
21	7	25
22	6	24
23	-8	19
24	-7	17
25	2	13

Table 30 X and Y results (Source: Author´s elaboration)

In this way, the number of students, located by quadrant of learning style was (Figure 20):

- Converging: 2 (8%)
- Assimilating: 3 (12%)
- Accommodating: 6 (24%)
- Diverging: 14 (56%)

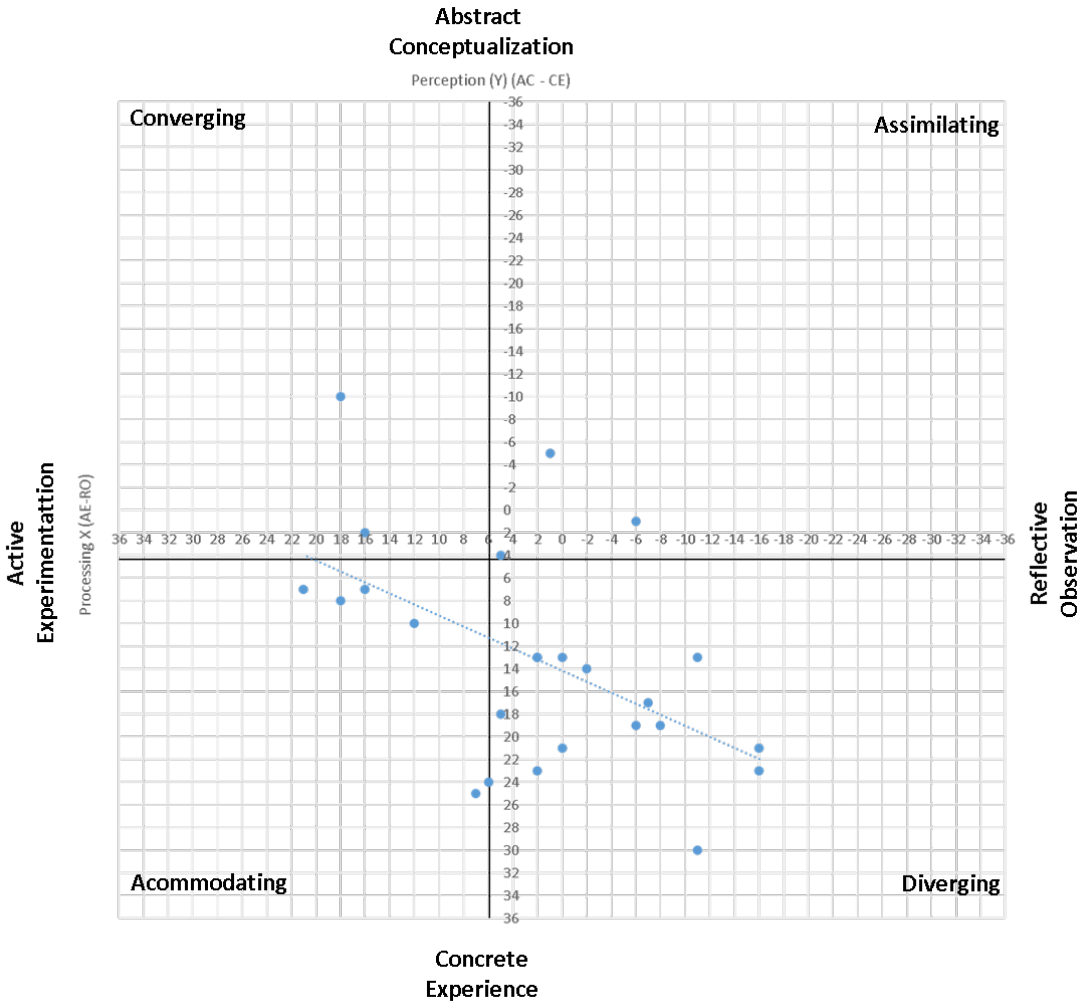


Figure 20 KOLB´s stages of the learning cycle for student (Adapted from www.victorhugolara.wordpress.com)

It was observed that 56% of the students who participated (92.6% - 25 of 27) expressed a preference for a divergent learning style (Quadrant IV), made up of the Concrete Experience and Reflective Observation styles. As mentioned before, Kolb's Experiential Learning Cycle is made up of four stages that, although they constitute a continuous process, are organized sequentially from the generation of a concrete experience (CE) through the development of an activity, followed by the reflection and observation (RO) of this experience to get to acquire abstract concepts (AC) when working and thinking around the experience; to finally use this experience (AE) in planning future tasks.

In this way, the Kolb cycle was applied from the divergent quadrant by carrying out activities leading to the initial development of a specific experience, as has been evidenced in different investigations and works such as those carried out by [54], [69], [70]

4.2.2.2 VARK Form

This form was selected because it allowed in a simple and fast way, rather than determining the different learning styles questioned in various studies (as mentioned in section 2.5); establish the preferences and abilities that students have to develop their learning processes, and adapt them to a non-face-to-face mode by implementing different strategies and instruments that privileged self-learning, based on the type of the course and information technologies related to Internet use.

The data relating to the VARK form are listed in Appendix 10 (Excel © Format). Table 31 shows the compendium of the VARK questionnaire results, filled out by the students, and Table 32 shows the percentual results.

Student	Learning Style	Frecuency	Position	Student	Learning Style	Frecuency	Position
1	V	1	4	14	V	3	3
	A	4	3		A	1	4
	R	5	2		R	8	1
	K	6	1		K	5	2
2	V	8	4	15	V	2	1
	A	12	1		A	8	1
	R	10	3		R	6	2
	K	11	2		K	5	3
3	V	3	4	16	V	3	4
	A	9	2		A	7	2
	R	7	3		R	5	3
	K	10	1		K	11	1
4	V	3	4	17	V	5	2
	A	4	2		A	7	1
	R	6	1		R	4	3
	K	4	2		K	5	2
5	V	9	3	18	V	12	1
	A	13	1		A	12	1
	R	8	4		R	8	4
	K	10	2		K	10	3
6	V	3	4	19	V	7	4
	A	5	1		A	11	1
	R	4	3		R	8	3
	K	5	1		K	9	2
7	V	5	3	20	V	6	2
	A	7	1		A	10	1
	R	7	1		R	6	2
	K	3	4		K	10	1
8	V	7	2	21	V	2	3
	A	5	4		A	7	1
	R	6	3		R	2	3
	K	9	1		K	5	2
9	V	7	3	22	V	10	2
	A	11	1		A	7	3
	R	7	3		R	6	4
	K	8	2		K	13	1
10	V	7	3	23	V	5	3
	A	12	1		A	7	2
	R	8	2		R	5	3
	K	6	4		K	8	1
11	V	7	3	24	V	2	4
	A	10	1		A	10	1
	R	9	2		R	7	3
	K	6	4		K	8	2
12	V	3	3	25	V	5	2
	A	4	2		A	5	2
	R	6	1		R	9	1
	K	3	3		K	9	1
13	V	6	4				
	A	8	2				
	R	7	3				
	K	10	1				
							Position
				TOTAL	**V**	**131**	**4**
					A	**196**	**1**
					R	**164**	**3**
					K	**189**	**2**

Table 31 Compendium of results of the VARK questionnaire (Source: Author´s elaboration)

Student	Learning Style	Frecuency (%)	Position	Student	Learning Style	Frecuency (%)	Position
1	V	6	4	14	V	18	3
	A	25	3		A	6	4
	R	31	2		R	47	1
	K	38	1		K	29	2
2	V	20	4	15	V	10	1
	A	29	1		A	38	1
	R	24	3		R	29	2
	K	27	2		K	24	3
3	V	10	4	16	V	12	4
	A	31	2		A	27	2
	R	24	3		R	19	3
	K	34	1		K	42	1
4	V	18	4	17	V	24	2
	A	24	2		A	33	1
	R	35	1		R	19	3
	K	24	2		K	24	2
5	V	23	3	18	V	29	1
	A	33	1		A	29	1
	R	20	4		R	19	4
	K	25	2		K	24	3
6	V	18	4	19	V	20	4
	A	29	1		A	31	1
	R	24	3		R	23	3
	K	29	1		K	26	2
7	V	23	3	20	V	19	2
	A	32	1		A	31	1
	R	32	1		R	19	2
	K	14	4		K	31	1
8	V	26	2	21	V	13	3
	A	19	4		A	44	1
	R	22	3		R	13	3
	K	33	1		K	31	2
9	V	21	3	22	V	28	2
	A	33	1		A	19	3
	R	21	3		R	17	4
	K	24	2		K	36	1
10	V	21	3	23	V	20	3
	A	36	1		A	28	2
	R	24	2		R	20	3
	K	18	4		K	32	1
11	V	22	3	24	V	7	4
	A	31	1		A	37	1
	R	28	2		R	26	3
	K	19	4		K	30	2
12	V	19	3	25	V	18	2
	A	25	2		A	18	2
	R	38	1		R	32	1
	K	19	3		K	32	1
13	V	19	4				
	A	26	2				
	R	23	3				
	K	32	1				

Table 32 Compendium of results of the VARK questionnaire (Percentual) (Source: Author´s elaboration)

An important result found with the application of the questionnaire was that 100% of the students made a multimodal selection for the four learning styles. For this reason, it was not possible to determine a stratification of preferences regarding these learning styles. Therefore, the different preferences were totaled in order from highest to lowest score. The styles favored by the students were presented in the following order:

- Aural
- Kinesthetic
- Writer / Reader
- Visual

The total number of students´ answers for each learning style was divided by the total of answers for the course, thereby determining the percentage of preferences for each learning style. (Figure 21)

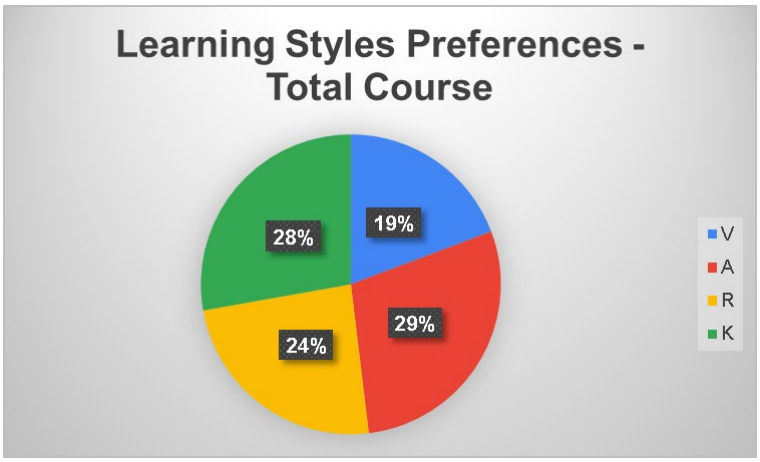


Figure 21 Answers for each learning style preference (Source: Author´s elaboration)

The percentage differences (Table 33) of the totals obtained for the course were calculated, to determine differentiated strategies, according to different preferences, to facilitate online learning for students. The highest differences were found between the Auditory-Visual and Kinesthetic-Visual styles, with values of 10% and 9% respectively. However, in general, the differences are not high.

	A	K	R	V
A	0	1	5	10
K	(-)	0	4	9
R	(-)	(-)	0	5
V	(-)	(-)	(-)	0

Table 33 Percentual differences of totals of learning preferences (Source: Author´s elaboration)

This result privileged the implementation of content based on the different sensory modes, taking advantage of the preferences and abilities of each student according to their cognitive development and the type of course. An additional aspect is that according to [], the consistency between the results obtained and the multimodal characteristic of online learning and the use of ICTs was used.

4.3 Intervention Proposal from Diagnosis Results

Based on the results obtained in the interviews and surveys, the structure for learning in non-face-to-face mode of the subject Metalworking Processes Workshop was proposed, using the Problem Based Learning methodology. The following parameters were taken into account:

Structural parameters from the results of the interviews:

- Participation of the teacher as a facilitator of communication between students.
- Implementation of virtual workspaces through the use of platforms such as Google Meet ©, Zoom ©, Moodle © and repositories such as Google Drive ©
- Use the teacher's previous digital training, as a mechanism for implementation and dissemination of content through the use of ICTs. This experience was used to search for specific tools (for example, digital boards) and self-learning processes on their management and implementation, with integration of resources developed from face-to-face.
- Development and use of specific content for learning processes in a non-face-to-face mode (PowerPoint © presentations, YouTube © videos related to the topics of the course)
- Promotion of the use of specialized software licensed by the University, to be downloaded at home (for example AutoCad ©, Inventor ©, Solid Edge ©) or to be used by remote connection to servers in laboratories (for example Flexim ©).

- Promotion of the use of free simulation software in manufacturing such as that supplied for work by computerized numerical control from Fagor Automation © or trial versions such as CNC SimulatorPro ©.
- Making adjustments to the methodological aspects of the course, to be developed virtually through the use of free interactive digital boards such as OpenBoard © (https://openboard.ch) and Idroo © (https://idroo.com)
- Opening of spaces by the teacher for advisory activities after class hours to carry out asynchronous advisory sessions.
- Implementation of hybrid evaluation processes through the use of the Moodle © platform to carry out online evaluations, and Google Meet © or Zoom ©, to implement evaluation spaces through exhibitions of the solution results to manufacturing problems.

Structural parameters from the surveys:

- Autonomous Learning/Colaborative Learning:

    - Promotion of autonomous learning, for the development of different course contents from the use of various documents, texts, bibliographic references, and so on; Through the use of study techniques that the student has used or wishes to use, with privilege in the development of exercises, the realization of drawings and diagrams, summaries.
    - Generation of spaces for collaborative work, through the creation of individual rooms for each of the work groups, during synchronous sessions, so that the participation of students is privileged freely and spontaneously.
    - Promotion of collaborative learning as a complement to autonomous learning, to promote academic and social interaction, critical thinking, as well as the development of soft skills and the use of technical language.

- Learning Preferences

    - Kolb's experiential learning cycle

      With the application of the inventory of learning styles of Kolb, in addition to identifying the possible study preferences of the students, we proceeded to take these as a basis for the establishment of learning activities related to the pre-established training objectives.

        - First stage: Concrete Experience – Providing to students, for the development of individual autonomous work, primary readings of texts related to specific study topics, problem sets, specific examples, case studies. Likewise, provide a template for the study file so that they can carry out, on a voluntary basis, the corresponding summaries (Appendix 11)

        - Second stage: Reflective Observation - Promotion through teamwork and virtual sessions of the course, holding discussions and questions on the specific topics covered, as well as feedback.

        - Third stage: Abstract Conceptualization - Development of abstract concepts and generalizations, with which the student consciously or unconsciously generates specific information leading to the solution of the problem. Here knowledge is organized, and processes are identified that are classified in the form of patterns. The student will be able to apply the knowledge in different scenarios.

- Fourth stage: Active Experimentation - In this stage, knowledge is condensed, so that the student can apply it in a systemic and systematic way to a situation that they will encounter during professional practice. As new challenges and problems develop, the cycle begins anew, enriched with previous experiences.

- VARK Questonary

According to [71], it is feasible to select and implement different tools for each learning style (Table 34)

Visual	Aural	Read-Write	Kinesthetic
Diagrams	Debates, Arguments	Books, Texts	Real-Life Examples
Graphis	Discussions	Hadouts	Examples
Colors	Conversations	Reading	Guest Lecturers
Charts	Audio Tapes	Written Feedback	Demonstrations
Written Texts	Video + Audio	Note Taking	Physical Activity
Different Fonts	Seminars	Essays	Constructing
Spatial Arrangements	Music	Multiple Choice	Role Play
Design	Drama	Bibliographies	Working Models

Table 34 Proposal of tools for each learning style (VARK). Taken f [72]

On the other hand, in accordance with con [71], and based on the resources currently available in the Faculty of Engineering and in the home as an "academic space" due to mobility restrictions, a set of tools for the non-face-to-face learning modality, based on VARK, as shown in Table 35. From the proposal of de [71], the use of the following resources was established:

VARK Style	Tools that can be used in virtual environments
Visual	Video, vodcast, Power Point © presentationswith images
Aural	Power Point © presentations with videos with audio, multimedia, conversations
Read/Write	Power Point © presentations with text, specialized books, homeworks, readings, study sheets
Kinesthetic	Multimedia interactivity, simulators, real life problems solving with foundatios on PBL.

Table 35 Tools to be used in a virtual environment. Adapted from [72]

The elements required to apply the PBL methodology in a non-face-to-face learning modality must include learning spaces, spaces for synchronous and non-synchronous advice, learning materials, as well as technological tools that favor training in virtual environments. and allow communication. Thus, based on

the above and from the results of interviews and surveys, the common elements were determined and it was found that it is essential:

- The implementation of virtual learning spaces for the promotion of collaborative work, in a coordinated way, for the development of activities and interaction based on ideas and knowledge, argument exchange, social interaction; as necessary elements for the search and generation of the solution of the problem posed for each group and as a complement to autonomous learning. In response, the use of platforms such as Google Meet © or Zoom © was promoted to carry out synchronous and asynchronous sessions. The Moodle © platform was also used because it is characterized by allowing the deployment of "strategies focused on the individualization of teaching, strategies for group teaching; focused on the presentation of information and collaboration, and strategies focused on collaborative work" [73]. The use of collaborative communication spaces such as Google Currents © was also promoted.
- The use of repositories such as Google Drive © and Moodle ©, as databases for managing files and information.
- The implementation of virtual spaces for work and autonomous learning. This need was responded to through the development of personal learning environments (PLE), which students would use voluntarily. It was proposed to use the Symbaloo © online platform, as it is free.
- The implementation of virtual consulting spaces, with the participation of the teacher or the course monitor. These spaces will be used mainly in non-synchronous mode. For this, the commitment of the teacher is required to guide and contribute, based on their professional experience and disciplinary knowledge.
- The development of these spaces, as a means of communication between students at the group level and between students and teacher.
- The selection, implementation and teaching resources focused on the use of ICTs, as support for autonomous and collaborative learning processes. Presentations were used in PowerPoint © with text and videos, files in Acrobat .pdf ©, electronic boards such as Idroo © and OpenBoard ©.
- The implementation of technological resources such as specialized software (AutoCad ©, Inventor ©, Solid Edge ©), Microsoft Office suite software © and simulation software (free such as Fagor Automation © and in a trial version such as CNCSimulator Pro ©) that allow the theory to be deployed to practical application scenarios.

Given that the objective of this thesis was oriented to the determination and implementation of the changes in the curriculum required to apply the PBL methodology in a non-face-to-face learning modality generated by COVID-19, the associated steps were considered to work with this methodology. Initially, seven work groups were formed, six of four and one of three, for a total of 27 students, and each group was assigned a problem of manufacturing an object, as shown in Table 36.

GROUP	MANUFACTURING PROBLEM
1	Blender
2	French Horn
3	Disc brakes
4	Electric guitar
5	Transverse flute
6	Water Pump
7	Screw jack

Table 36 Problem of manufacturing (object) assigned by group (Source: Author´s elaboration)

The structuring of the PBL in a non-face-to-face mode was carried out based on the elements mentioned above, considered as a prerequisite.

Then, the steps involved in the problem-based learning methodology were deployed for each assigned manufacturing situation. In this way, it began with the clarification of terms and concepts, according to each problem and based on the course modules (Syllabus - Appendix 1). As support material, specific technical readings, videos related to the particular theory were provided. For example, for module 1 regarding the Importance of Matter, Process, Manufacturing, Manufacturing Process, Production Systems, the reading of books such as “Automation, Production Systems, and Computer-Integrated Manufacturing, 5th Edition, Mikell Groover, © Pearson "and" Fundamentals of Modern Manufacturing: Materials, Processes, and Systems, Mikell P. Groover, © Wiley. " YouTube © videos such as “How Its Made Wood Model Aircraft” (https://www.youtube.com/watch?v=3m-3lyZnYdA) were also used for the concepts of manufacturing and manufacturing process and “Ford Historic Model T ”and“ How It's made magnets ”(https://www.youtube.com/watch?v=noGGcyPHtdI) for the concepts of manufacturing system, manufacturing support activities, type of production systems.

This phase of the process was carried out in accordance with the first stage of Kolb's experiential learning cycle (Concrete Experience), since it allowed the use of materials such as those mentioned in previous sections. Likewise, it allowed to generate scenarios for autonomous learning such as personal learning environments (PLE), and collaborative learning on the different platforms.

The definition of the problem continued, by means of which at the group level and in a collaborative way, it was sought to reach a consensus on the concepts that should be explained and involved, within the framework of the manufacturing problem and the theoretical content involved. Then the problem was analyzed, by collecting the opinions of the members of the group, to start with the formulation of hypotheses aimed at solving the manufacturing problem. In this way, it was sought to critically determine what theoretical elements should be addressed and estimate how they could be applied. This work was complemented with workshops such as the one shown in Appendix 12 and specific questionnaires. The use of collaborative learning spaces was privileged through group sessions on Google Meet © or Zoom ©.

These two phases of the process were related to the second stage of Kolb's learning cycle (Reflective Observation)

This was followed by a systematic inventory of the different explanations and elements of the problem. For this, the technological analysis methodology was applied, which allows visualizing the manufacturing object, as a problem situation, from technical, morphological, functional, historical, economic, and social perspectives. For the specific case of the course, we worked on morphological, functional, and technical analyzes. Based on the above, the learning objectives were raised based on the technological analysis related to the processes involved for the manufacture of the object. In this way, the students developed the ability to answer questions such as, what is the manufacturing sequence that I must establish? What manufacturing processes allow me to transform raw materials to obtain the required shapes, meeting the requirements of precision, quality? and functionality? Thus, the objectives were associated with the proposal of a manufacturing range.

This phase was related to the third stage of Kolb's learning cycle. (Abstract Conceptualization)

With the sixth and seventh phases of the process, based on autonomous and collaborative work, a plan for the manufacture and assembly of the object selected as a problem situation was established. This manufacturing plan, established in a manufacturing range, responds to how to manufacture, from the knowledge of the manufacturing processes, in a systemic and systematic way, an object.

This last part is coherent with the fourth stage of Kolb's cycle (Active Experimentation), where the student learns by “doing”.

4.4 Autonomous and Colaborative Learning

Different spaces were proposed to promote autonomous and collaborative work, for the development of the methodology of learning based on problems in a non-face-to-face way. According to the results obtained in the survey (Numeral 4.2) and opinions extracted from the interviews (Numeral 4.1), the following were implemented:

- A learning community with the use of the Google Currents © application
- A space for the development of a Personal Learning Environment (PLE), with the free Symbaloo © platform

Likewise, different sources of information and consultation, software for document generation and forms of participation through applications and spaces were recommended for autonomous and collaborative learning, such as:

Yotube ©, Web links, Excel ©, Google docs ©, .docx files, Images, .pdf files (web links), Technical drawings, Meet videos, Meet Audio, .ppt presentations

No restrictions or conditions of use were established and the possibility of using other applications according to the needs and preferences of the students, based on their own academic experience, was left open.

The consolidated participations in Symbaloo and Google Drive by work team, were consolidated in the Appendix 13. This file includes the links to the Symbaloo portal (C), as well as to the Google Drive platform (C), through which the contributions made by students at an individual and group level can be observed.

4.4.1 Learning Community Results

Through Google Currents ©, a learning community was established for Metalworking Process Workshop course for 2020-02 semester. The objective of this space was to favor a form of individual and or group participation of students, share knowledge, documents, generate discussion processes, and collaborate. The data was organized into electronic sheets (Microsoft Excel ©) (Appendix 14). The appendix file relates participation counts as their type discriminated as participation in discussions, input of documents, videos, individual comments among other aspects. Participation in this space was established as voluntary. Table 37 shows the details of participation and interaction:

GROUP (Size)	Student participation	Contribution				Ask related with topics of the course	Ask without relationship with topics of the course	Interaction between students, related with topics of the course	Interaction between students, without relationship with course topics
		Videos	ith attachment (R	h attachment no	Asks				
1(4)	1	0	0	0	3	2	1	0	1
2(4)	2	0	0	1	3	1	2	0	0
3(4)	1	0	2	0	0	0	0	0	0
4(4)	3	0	1	0	9	6	3	0	0
5(3)	3	0	2	0	5	2	3	1	2
6(4)	2	0	1	0	1	1	0	0	0
7(4)	1	1	3	0	0	0	0	0	0
	13	1	9	1	21	12	9	1,0	3
	48,1	3,1	28,1	3,1	62,5	57,1	42,9	3,3	10

Table 37 Participation and interaction of students in Google Currents plataform during 2020-02 (Source: Author´s elaboration)

By establishing itself as a space in which collaborative work was sought to be privileged, there was the voluntary participation of 13 students out of a total of 27 enrolled in the course, that is, 48.1% (Figure 22).

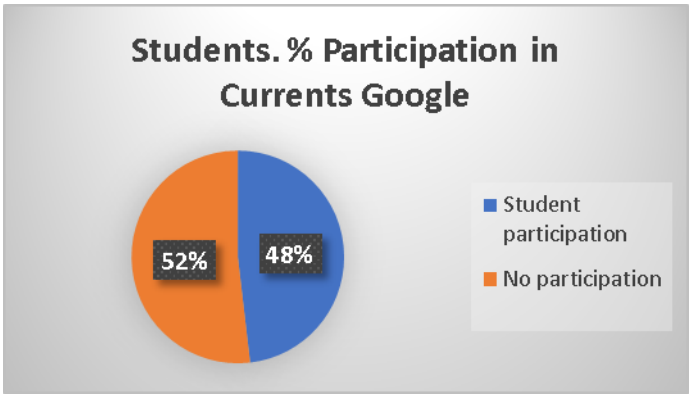


Figure 22 Student's participation in Google Currents 2020-02 (Source: Author´s elaboration)

The average participation rate was 1.8571 students with a standard deviation of 0.8997. Furthermore, Q1: 1, Q2: 2 (Median) and Q3: 3. No data were presented for Q4.

The total participation of these students was 30, with 36 contributions discriminated as shown in Figure 23.

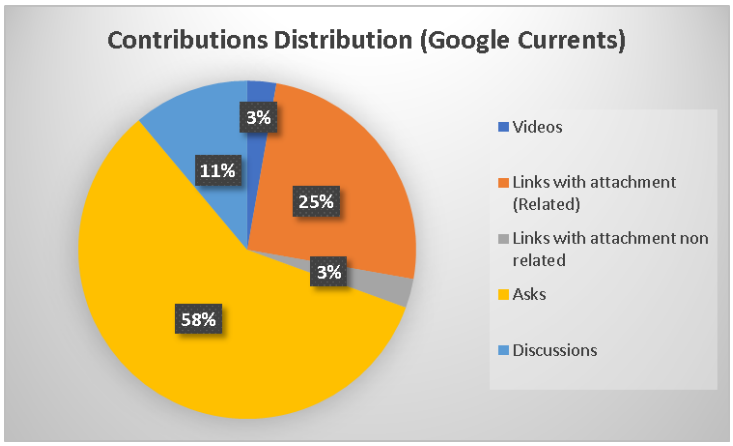


Figure 23 Contributions distribution in Google Currents © (Source: Author´s elaboration)

Although participation was close to 50% of the course, 58.3% of the interactions were developed through questions. Of these, 57.1% were questions related to the themes of the course and (42.9%) questions not related to the content of the course (Figure 24)

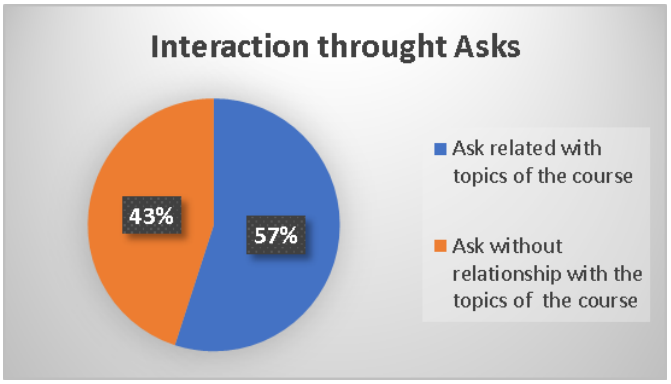


Figure 24 Interaction through Asks (Source: Author´s elaboration)

The remaining 34.4% of the participations were contributions with links to sites of interest on the Internet. The distribution is shown in Figure 25.

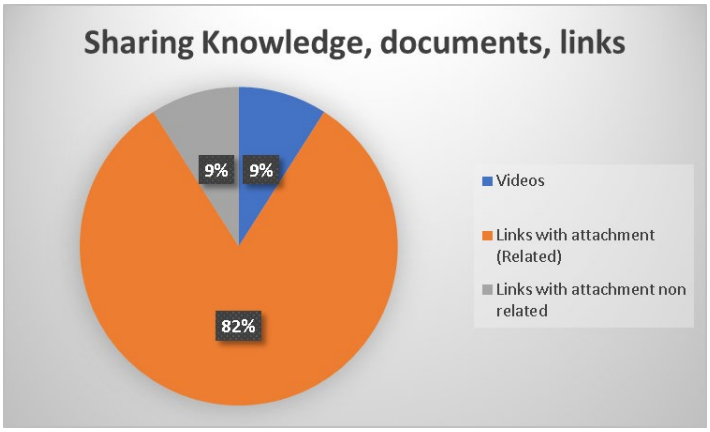


Figure 25 Sharing knowledge, documents, links. (Source: Author´s elaboration)

Most of the contributions were related to document consultation links (9) (82%) without privileging other types of significant contributions such as presentations, videos (One (1) 9%), different types of files (.pdf, .docx, .xlsx, and so on), contributions associated with work in progress in the course.

Regarding interactions between students (discussions), these correspond to 11% of the contributions on the platform (Figure 25). Of this 11%, 75% (3 discussions) were held on topics other than the subject matter of the course content and only 25% (1 discussion) were related to a theoretical aspect of the course. (Figure 26)

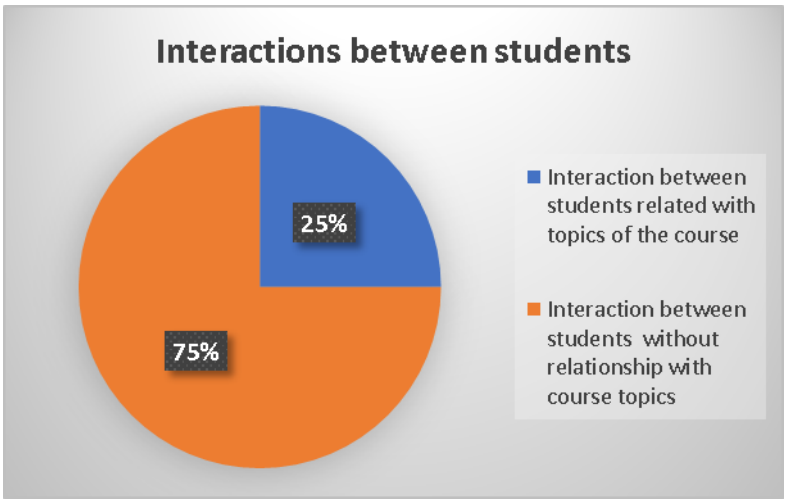


Figure 26 Intercation between students (Source: Author´s own elaboration)

During the 2020-01 academic period, a collaborative learning space was also established through the same platform (Google Currents ©), but a percentage of the final grade for the course was assigned to participation. Table 38 shows the corresponding consolidated and in Figure 27, the percentage distribution.

Participations in Google Currents	
Type of Participation	Quantity
Link/Documents/Videos	192
Comments about topics of the course	279
Asks	35
Discussions	197
Total:	703

Table 38 Total participation in Google Current in first semester 2021 (2021-01) (Source: Author´s elaboration)

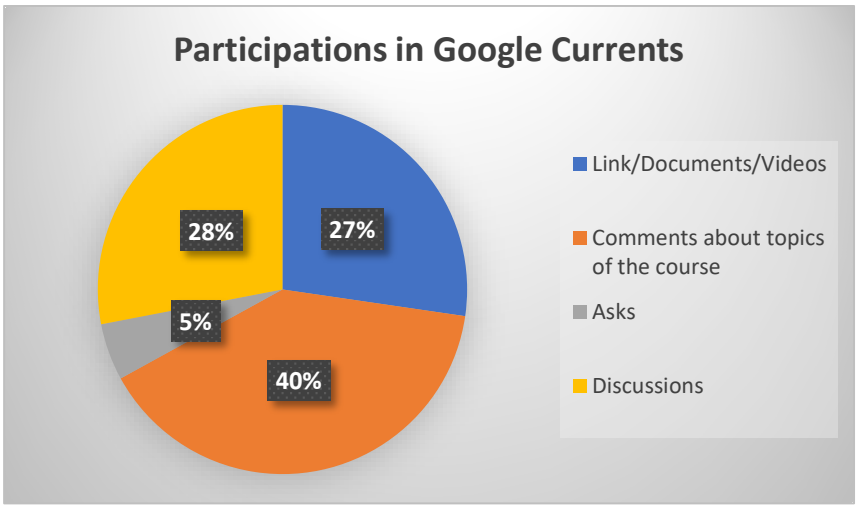


Figure 27 Participation in Google Currents © 2021-01 (Source: Author´s own elaboration)

It could be thought that having established a percentage of the final course grade in the 2020-01 period for contributions in the community in Google Currents ©, increased the participation of students (96.88%). However, the contributions made were grouped as shown in Table 39 and Figure 28. Thus, 83.3% correspond a contributions between 1 and 30.

Interval of contributions	Frecuency	Percentage
≤ 10	10	33,3
>10 ≤ 20	11	36,7
>20 ≤ 30	4	13,3

Table 39 Frecuency and percentage of the intervals of contributions during 2020-01 (Source: Author´s elaboration)

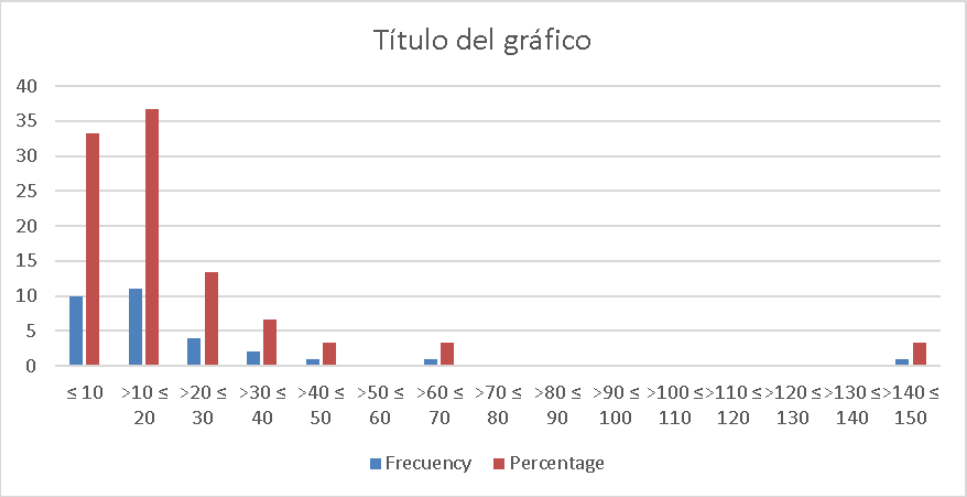


Figure 28 Frecuency and percentage of the intervals of contributions (Source: Author´s elaboration)

It can be seen that, 83.3% of 703 contributions were concentrated in the interval between 1 and 30. Likewise, 149 contributions (3.3%) were made by a single student. For intervals greater than 70 and less than 140, no contributions were made.

4.4.2 PLEs and Drive Results

At the beginning of the course, students were proposed to use an online application, in a free version, as a space for them to voluntarily create their own personal learning environment (PLE), as a strategy to favor autonomous learning. After searching different links on the internet and evaluating various capacities, the Symbaloo © platform (https://www.symbaloo.com/home/mix/13eOhL2CYP) was selected.

Figure 29 shows the access portal to the register process. The general dynamic takes place between a Symbaloo created by the teacher, to which the students' Symbaloo are linked, with the aim of monitoring and providing feedback on their work.

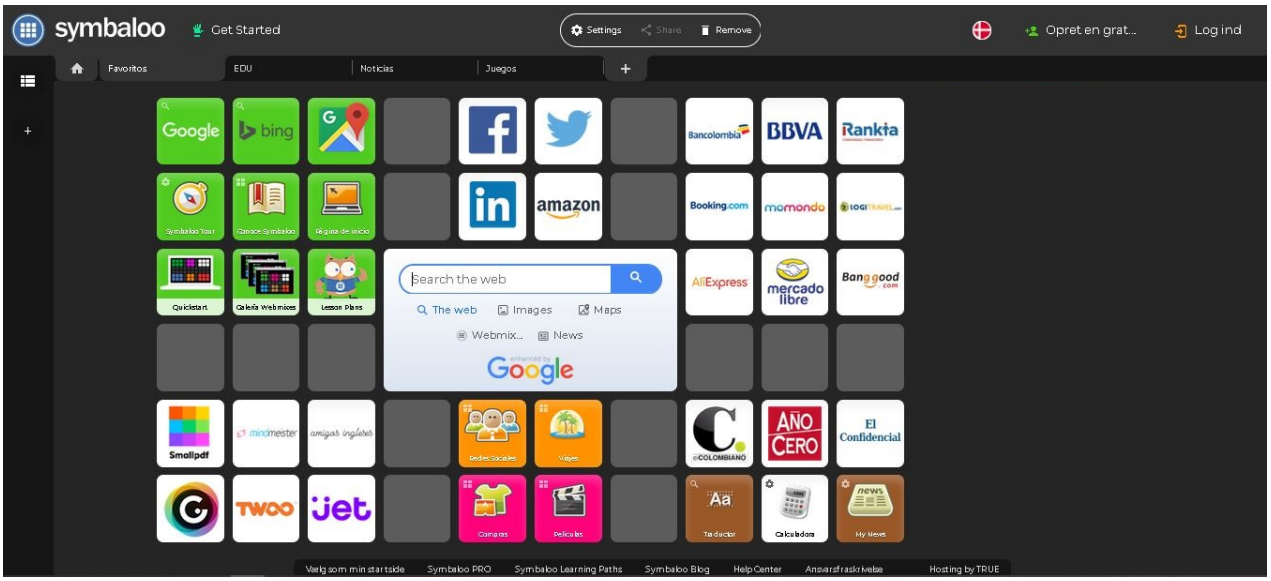


Figure 29 Portal access and registration to Symbaloo © (Taken from https://www.symbaloo.com/home)

Figure 30 shows an example of a Symbaloo created by a student, linked and viewed from the teacher's Symbaloo.

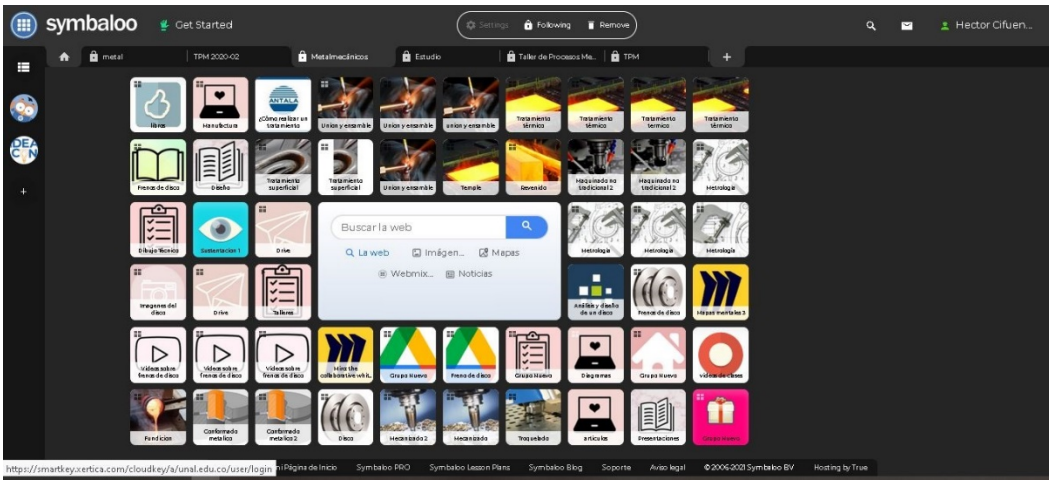


Figure 30 Example of a student's Symbaloo platform © (Taken from https://www.symbaloo.com/home)

This interface allowed interacting with the different spaces created by the student, such as book folders, manufacturing, technical drawing, presentations; as well as repositories of videos of classes or access documents in Google Drive © among others.

During the 2020-02 semester, 85.18% of the 27 students enrolled in the course created a PLE on Symbaloo©. Table 40 shows the consolidation of this participation, with the discrimination of the different contributions. This participation in Symbaloo (C) and Google Drive (C) can be found in Appendix 15:

TOTAL STUDENTS in Symbaloo	SYMBALOO		
	Youtube	Web links	PDF
23			
Total type of contributions	146	106	57

Table 40 Participation in Symbaloo. Number and type of contributions (Source: Author´s elaboration)

It is observed that this participation focused on three distinct groups: YouTube © videos, web links, and .pdf files. Figure 31 shows the percentage composition of the contributions. 47% contributed with videos from the YouTube © platform, 34% with links to sites of interest related to the topics of the course, and 19% with .pdf-type documents.

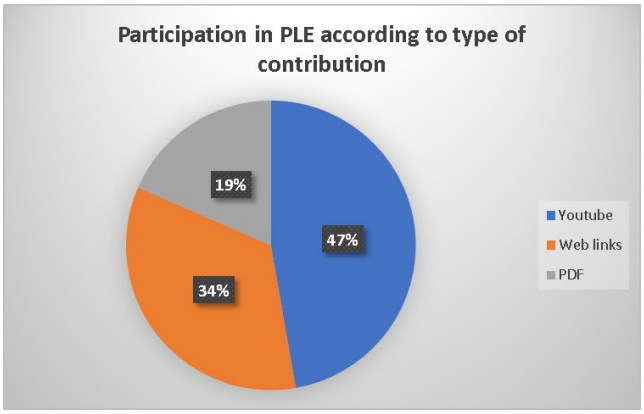


Figure 31 Percentual participation in PLE according to type of contribution (Source: Author's elaboration)

Figure 32 shows the contributions per student. It is observed that the dynamics of the students in relation to their participation was wide and visual and aural components were favored through videos; and read / write with .pdf files and web links.

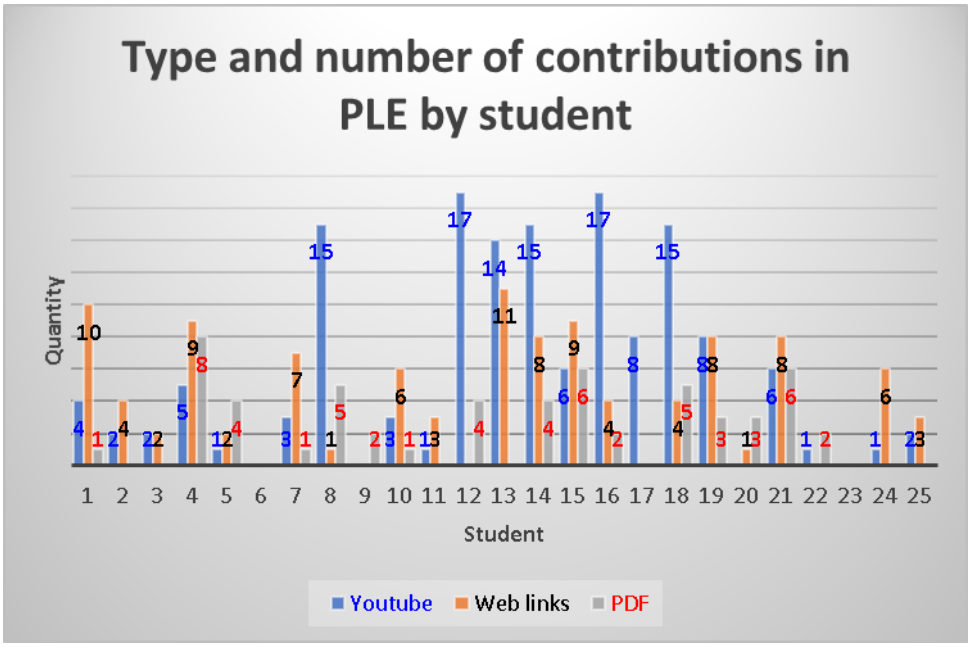


Figure 32 Type and number of contributions in PLE by student (Source: Author's elaboration)

At the beginning of the course, the use of Google Meet © as an individual repository of content and various types of files for students was also considered. Although the possibility of voluntary use of the Symbaloo © platform had been established, the students favored the use of the Drive, as a repository for autonomous and collaborative learning activities.

TOTAL STUDENTS in Drive	DRIVE								
	Excel	Google Doc	.docx file	Image	PDF File (web)	Technical Drawings	Meet video	Meet audio	.ppt Presentation
23									
Total type of contributions	35	46	15	71	53	94	221	11	8

Table 41 Participation of students in Google Drive. Number and type of contributions (Source: Author's elaboration)

Table 41 shows the participation of students in this platform. A greater variety of content deposited and used is observed, with a preponderance of videos related to recordings of synchronous and asynchronous sessions, with privilege of visual content, complemented with the use of images and technical drawings. Likewise, a wide variety of documents were deposited in Microsoft Office © suite formats, such as Excel ©, Word ©, PowerPoint ©. With the additional contributions of documents in .pdf format, a preferential component to the use of read / write content is observed.

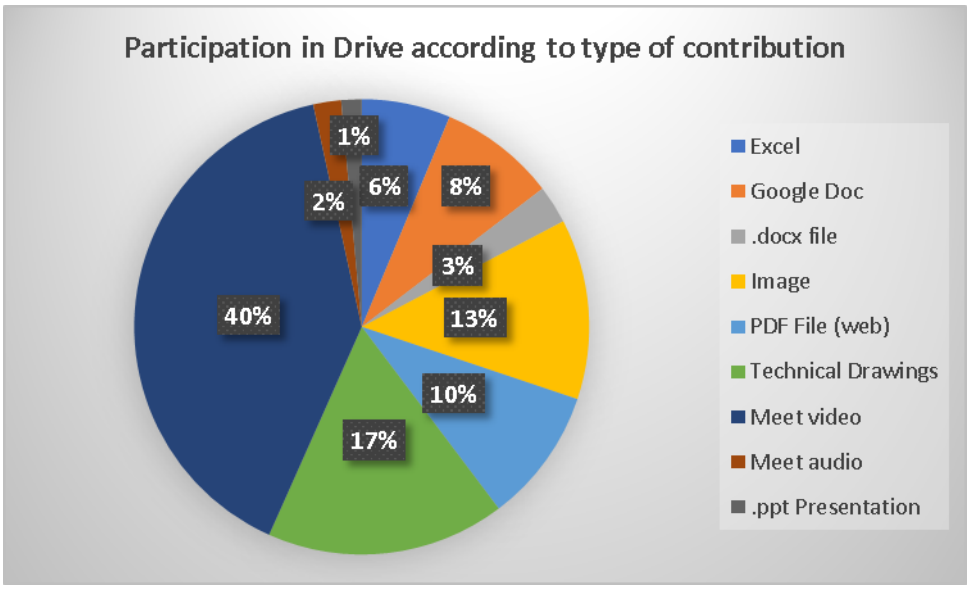


Figure 33 Percentual participation in Drive according to the type of contribution (Source: Author's elaboration)

In Figure 33, the percentage participation is observed according to the type of contribution in the Google Drive © platform. Again, the importance that students give to visual content made up of videos is validated. Images, technical drawings. Likewise, the importance of the use of reading / writing content is established. It is important to note that, despite not constituting an important contribution to collaborative work, the Google Docs © space was used to share editable files by students belonging to work groups.

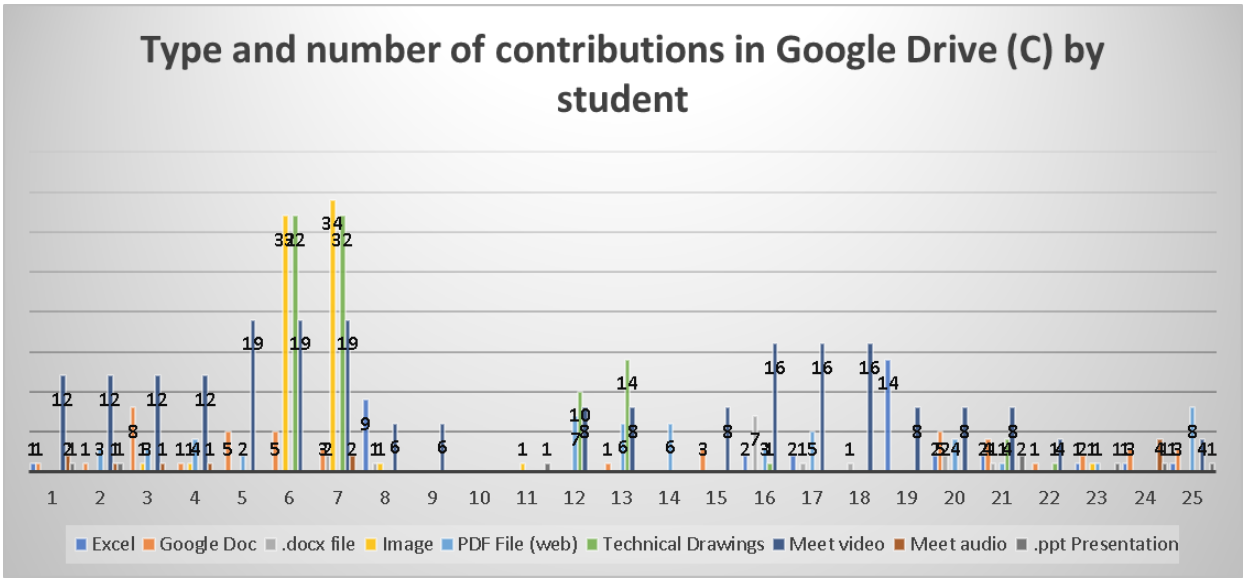


Figure 34 Type and number of contributions in Google Drive © by the student (Source: Author's elaboration)

Figure 34 shows the distribution of contributions by the student. Except for students 6 and 7, who made the most contributions, the contributions of the remaining students were similar and did not cover a wide range of content. Likewise, it is observed that some students had extremely low participation (one contribution) or zero (one student). However, the receptivity towards the use of this platform is

considered adequate. It should be noted that on the Symbaloo platform, the students directed a link to the Google Drive © platform.

5 Discussion

From the results obtained through the development of interviews and surveys, different changes were determined and implemented in some components of the curriculum to apply the PBL methodology in a non-face-to-face modality caused (still to date in Colombia) by the abrupt disruption in the learning modality caused by COVID-19 (SO 5). The criteria for determining the changes in the curriculum were established from the definition of the curriculum itself and the possibility of implementation based on availability, cost, and usefulness of the resources.

Academic resources: Support academic resources were implemented for asynchronous activities such as books shared in .pdf format through platforms such as Moodle, Google Drive ©; scientific articles are taken from databases such as Science Direct, electronic resources from the link HTTP: / /www.bases.unal.edu.co/subjects/databases.php; audiovisual support resources for synchronous and asynchronous work, such as specialized videos on free consultation manufacturing topics through platforms such as YouTube © (for example, https://www.youtube.com/c/mrpete222/playlists). According to the established learning objectives, these resources allowed the student to have information for their autonomous and collaborative learning activities.

Tablets: From the point of view of physical resources, a digitalizing tablet was implemented to carry out written interaction, images, and videos with the students in the synchronous sessions. For its acquisition, it had the support of the directors of the Faculty. This resource allowed, on the projection of PowerPoint © presentations, to make annotations to complement images or videos, or on "pages" in online digital boards such as OpenBoard ©, to develop complementary themes, explanatory drawings, annotations on pictures, and other conducive activities to clarify doubts and complement theoretical aspects. The virtue of this resource was visualized by its ability to interact with students in real-time and the possibility for the teacher to expand their communication capacity virtually. Thus, the use of the board in the classroom was transferred to a non-face-to-face setting, with the same magnitude of exchange and sometimes with greater possibilities when interacting with the different academic materials, in a way not easily achievable in the classroom.

It should be mentioned that the use of this physical resource also impacted the related teaching-learning methodology.

Interactive Whiteboard: The curricular component that it replaced was related to the didactics associated with using the whiteboard in the classroom. This strategy was implemented to interact dynamically with the students, allowing the creation of annotations, the development of explanations on presentations, and the sharing of content such as images, videos, documents. Also, as an interactive space for resolution of doubts, the extension of explanations with the support of contents inserted in real-time on the virtual screen; from other spaces such as YouTube ©. Its use was established through shared screens online with meeting platforms such as Google Meet ©, Zoom ©. For the development of this thesis, the free tool OpenBoard © was selected. This interaction added to the use of the tablet and the platforms mentioned above, transferring the use of the board from the face-to-face to the virtual, with greater possibilities associated with the help of different didactic materials.

Platforms for a video conference: For the development of classroom programmatic content, based on the problem-based learning methodology (PBL) in a non-face-to-face mode, platforms for video conferencing were implemented to guarantee real-time remote interaction with the students. Communication through

video, sound, and text; online. The Google Meet © and Zoom © platforms were used. These platforms made it possible to share images, texts, videos, and other instruments such as Interactive Whiteboards. With these platforms, it was possible to dynamize the development of solving industrial manufacturing problems, according to the PBL methodology, since together with the items mentioned above, they allowed to generate a collaborative workspace based on the development of discussions, solution of doubts, exposition of specific theoretical aspects, among other elements. It should be mentioned that through these virtual platforms, asynchronous consultancies were also developed during which they worked with the students on the specific problems they had to solve during the course of the semester.

Simulation software: To approach laboratory practices, as a component of the curriculum associated with experimental processes related to transformation through manufacturing activities, simulation software was used to recreate a process, activity, phenomenon, or behavior. For the specific case of the course, this type of software made it possible to "carry out" machining activities online since it generated an environment similar to that faced by the student in a face-to-face laboratory practice or a manufacturing situation in the professional field. It allowed recreating the operations associated with a specific machine (lathe). The software "Late Machine Simulator" from the firm VirtualLabs Software © from Russia was used in its free version, both for conventional lathe and computerized numerical control (CNC) lathe. The use of electronic sheets such as Excel © for the development of calculations associated with the determination of manufacturing parameters should also be mentioned. However, the laboratory practice provides a sensory interaction that goes beyond the experimental, the simulation software, allowed to observe certain processes and activities in virtual reality.

The aspects mentioned earlier show that from the point of view of the curriculum, it is possible to address certain elements such as methodologies, didactics, physical and academic resources. However, there is evidence of a certain level of exhaustion on the students when facing the subject in this way. Proof of this is the low social interaction in the different virtual sessions.

Regarding the technological aspects, the situations concerning the Internet network infrastructure are not controllable by the students' families, themselves, or the University. This is an infrastructure policy situation in the country that, at present, although for urban areas, has improved, as evidenced by the statement by the Ministry of Information Technologies and Communications (MinTIC) in its most recent report on According to the news published in the weekly Portfolio for the first quarter of 2021 [74], figures from the sector have not been so for rural areas, for which it was intended to "guarantee free access to the WiFi wireless Internet service for up to 10,000 rural communities with a long-term and uninterrupted operation" [75]. This scandalous situation deprived rural schools and rural regions of access to the Internet, in addition to the detriment to public money of more than 70,000 million pesos from the State (approximately € 15,930,000, oo).

Regarding technological devices such as computers, cell phones, and tablets, the situation is different. In the case of computers, if its structure allows updates such as RAM expansion, installation of SSD-type hard drives; The problem associated with the lack of technical capacity to use specialized software and simulators, for example, would be surmountable. However, this would require investments that not necessarily families in this pandemic situation could cover, since many of them saw their income decrease due to job losses, which by 2020, according to DANE, stood at 15.9%, compared to 10.5% for the year 2019 [76]. Thus, it is difficult to establish how this situation could improve since it depends on the economic aspects of a financial crisis. About cellular devices, making investments in SmartPhone type mobiles is not easy due to their high cost, even though they would have been the ideal ones to try to carry out interaction in a non-face-to-face mode. For tablets, the situation in particular, since despite what one might think, they do not have enough capacity to use specific applications of a specialized nature, added as in the previous case to their cost. Thus, its use and limitations would be similar to that of a Smartphone.

Therefore, it would have been ideal for all students to have a computer with adequate technology to fully develop learning processes in a non-face-to-face mode.

An important aspect is the implementation of manifest soft technology with specialized software such as AutoCad ©, Solid Edge ©, Inventor ©, Flexim ©; in addition to the Office suite, especially Word ©, Excel ©, PowerPoint ©. It should be noted that the University has access to these licenses, although in some cases, it is limited and is subject to the use and connection with servers located on the Campus; therefore, for some situations, there are not enough licenses and access for all students. Likewise, concerning simulation programs, access is also restricted by the number of licenses and use of servers. As the University does not have all the variety of simulation software or is very expensive, it is necessary to use free software or trial versions (demo) with the restrictions imposed by the manufacturer; that generates limitations in the learning processes by not having all the required facilities available according to the discussed topics.

From the point of view of the teacher´s activity and their ability to face a teaching scenario in a non-face-to-face situation, as a University policy, there had not been, nor have they been implemented curricular transformation policies that involve, in addition to the environment of presence, specific processes of teacher training in the different pedagogical methods required and appropriate to virtuality. Although contingency measures were established to face the situation related to disruptive changes, an effect of the COVID19 pandemic, these were not due to a structural change in the curriculum that is now necessary, but that must be established within a process that will surely have to lead to an academic reform in the University. For this purpose, it will require the participation of the different educational establishments, which will require the implementation of spaces for proposals and discussions, with the corresponding times and moments and the appropriation of financial resources that this reform will need.

Thus, the teaching activity has become difficult, not only due to ignorance or lack of skill but also because on many occasions, the same teachers had to invest their financial resources to acquire technologies to improve the teaching-learning process from home, unsuccessfully transformed into academic space. It should be noted, in the particular case of the Faculty of Engineering, that it tried to contribute to the improvement of the processes, with the acquisition and assignment for some professors who manifested it, of digitizing tablets, which allowed interacting with the students in scenarios virtual, through spaces such as Google Classroom ©, Google Meet ©, Zoom ©, among others. Additionally, with the complimentary use of digital boards such as OpenBoard ©. In my particular case.

Despite the above, even to date, many professors still have difficulties in their non-presence activity, a situation that will last in the particular case of the National University of Colombia until February 2022.

Regarding the realization of courses in a virtual modality, this must be visualized in two scenarios: Pandemic and Postpandemic. In a pandemic scenario characterized by disruptive short- and medium-term effects, the University must continue to fulfill its mission objectives. Thus, the completion of the different courses becomes compulsory. Although many subjects do not have in their structure and require in their training objectives, laboratory practices, they can be carried out without major impact on the ILO's, but with detriment to the social interaction of the different actors in the academic scene. With a practical component, other subjects are affected by not carrying out the practicals, with the consequent impact on the ILO's. It is possible to be mitigated using specialized and simulation software. However, the conceptual, perceptual, social, and sensory experience, which is achieved with the development of face-to-face laboratory practice, is not covered, with the consequent gaps and demotivation that may be generated in the students. Implementing experimental situations, perceiving the different physicochemical and social phenomena, and enjoying a practice scenario, is not replaced with any computer application, which only achieves a cold and dehumanized approach to the process.

One might think that this situation is identical in the application of the PBL. However, an aspect that makes a difference is related to the fact that, regardless of whether the practical component is required at certain

stages of the development of the subject, there is an additional ingredient that makes a difference and establishes the importance of the implementation of this methodology in a non-face-to-face way. This ingredient is related to the virtue of the PBL of allowing, through autonomous and collaborative learning, among other aspects, to apply the theory in the search for a solution to a problem contextualized within the framework of the professional practice of the engineer. Observing, even in non-presence, how the theory allows solving, with the help of science, adaptation problems of the human being, within the framework of the pedagogical processes associated with the PBL, makes it possible to develop it, even under conditions pandemic.

In a Post-pandemic scenario, an inventory of all the experiences acquired in the pandemic must be carried out to propose hybrid pedagogical processes that combine face-to-face and non-face-to-face activities. This proposal will enrich the training processes and give students greater freedom by generating spaces for broader actions that, according to one of the foundations of the PBL, will allow them to be the architects and responsible for the generation of their knowledge. However, it is reiterated that this must remain within the framework of a policy at the university level, with short, medium, and long-term objectives, with the necessary and sufficient reforms.

Regarding the curriculum and assessment, the impact on students is reflected in the fact that face-to-face training cannot transition to non-attendance without the required curricular reforms and designs. As one student stated, the curriculum of the National University of Colombia was not designed for this (referring to the situation generated by the pandemic). A curriculum cannot be adapted to a specific case, even less in a crisis. It's like trying to muddle through to comply. The teaching-learning processes are accelerated, content is condensed, the methodologies adopted are not necessarily the most appropriate, and the mission objective cannot be developed with the required efficiency and effectiveness at the end of the process.

The evaluation processes are the most affected in the remote modality. In the absence of a culture of unsupervised evaluation, by not conceiving and interpreting evaluation as a process of feedback and improvement, by not understanding that it is studied for life, for society, for humanity, and NOT for the grade, it is impossible to conceive these processes in virtuality. This virtuality, for the curricular component of the evaluation, leads, in a culture like ours (despite not being a generality) to a culture of deception, with mechanisms such as copying, the generation of temporary spaces through platforms (for example, WhatsApp ©), with the aggravation that at the end of the process, many students pass the course practically without having learned the minimum required.

One of the great impacts of this virtuality has been reflected in the increase in the teacher's work at home. Oral evaluations can be carried out with which, for theoretical aspects, the student's level of knowledge can be determined. However, this takes additional time, effort, and work. In addition to the above, the fact that this form of evaluation should complement the particular case of the Workshop on Metalworking Processes with exhibitions and files with calculation memories that show the development in the search for the solution of a manufacturing problem in a PBL environment. All this exceeds the time and moments available to the teacher and makes an evaluation as a process and forms of assessment as practice unmanageable.

Second discussion

Within the characteristics of the PBL, active learning centered on the student, autonomous learning, and collaborative learning is privileged in a space where the teacher assumes the role of facilitator and guide. The results obtained in the surveys carried out with the perception questionnaires on autonomous learning and collaborative learning show students' importance to these aspects, which are consistent with the PBL.

Although these are diverse, a wide variation is observed in the type of preferred technique regarding the study techniques. However, it is impossible to tell each student which strategy to use since they have a life history associated with their learning processes, which does not guarantee that they appropriate any specific method. This way, despite being an important factor for autonomous learning, as shown by the results of the surveys, it is not controllable by the teacher to induce the particular use of any technique. Therefore, rather than imposing, it is necessary to recommend a range of possibilities according to what is stated in the surveys to choose and develop their work. How to validate if the student develops autonomous learning processes but in a non-presence setting? To answer this question, the students were asked to locate on different platforms (Moodle ©, Personal Learning Environments, Google Drive ©) evidence of this work in .pdf or image formats; but at the same time, the concern that was generated was how to get this information to be attached to the different platforms. Due to the situation associated with the pandemic, it was established as a policy that the indicated actions be carried out voluntarily.

Third discussion

Although there is a wide variety of proposals and instruments to establish learning styles, each of them with various questions and favorable comments, the KOLB and VARK questionnaires were selected, but in the search to determine student learning preferences more than in determining specific styles.
Of the two methods used, the one that offers an approximation and coherence with the PBL is Kolb's method, as it is based on experiential learning, as a process based on reflection and continuous change based on acquired experiences. In addition, this method allowed, rather than placing the students in a specific quadrant associated with the learning cycle, to determine the initial stage of work to organize the course's development from there.

Therefore, it began with activities to generate concrete experiences, based on autonomous work from primary readings of texts related to specific topics of the study course (According to Syllabus - Appendix 1), problems, specific examples. Then, it continued with the second stage of the cycle, Reflective Observation, in which teamwork and collaborative learning were privileged, with virtual sessions of the course, the development of discussions, and questions on the specific topics covered. This phase was characterized by the students' motivation, who, in addition to the synchronous sessions, requested asynchronous sessions with the teacher's participation as facilitator and expert in industrial manufacturing activities.

Subsequently, the Abstract Conceptualization was developed, which allowed for conceptual generalization through workshops with similar problems to the one proposed at the beginning of the course as manufacturing analogies. Finally, Active Experimentation was worked on, in which the acquired knowledge was applied to solve the manufacturing situation associated with each problem, manifested with a set of required and specific manufacturing methods.

Thus, the Kolb cycle, as indicated, was not limited to determining a style or a preference but became a starting point for the cognitive development associated with each of the course modules according to the established Syllabus. This allowed a transition from the concepts related to lower-order cognitive processes to higher-order cognitive processes related to the analysis of specific manufacturing processes for the generation of particular manufacturing proposals as a solution to the problem.

The VARK method sought to determine preferences, but more from a sensory point of view. Contrary to the reports that are generally found in the literature, in which results are shown with unimodal or multimodal learning styles (two, three, or four styles), and a statistical validation is carried out to establish the preferred styles according to a specific order; The results obtained in the application of the method in this thesis, yielded for all the students who participated, multimodal preferences including the four styles. For this reason, a count and a percentage determination of these were carried out. Although I consider the lack of capacity of the instrument to stratify preferences should be questioned, it should be mentioned that a possible cause of this situation is due to the size of the population that answered the questionnaire,

which corresponded to 92.6% of the students of the course (25 of 27). Despite the above, different tools were selected and implemented that would satisfy the students' preferences according to the percentage composition obtained.

It should be noted that according to [77], multimodal learning environments allow the implementation of content in more than one modality, which for the particular case of this thesis, as a result of the survey, involves sensory, visual, auditory, and kinesthetic. On the other hand, multimodal virtual environments facilitate knowledge and improve care.

Because most students were oriented to multimodal learning styles (VARK), and based on similar preference percentages, it can be assumed that most students benefit from the implementation of active learning. Since these strategies allow reaching all students according to visual, auditory, reading/writing, and kinesthetic schemes, the above.

Fourth discussion

At the beginning of the 2020-01 academic period, the Google Currents © platform was created and promoted as a space to share content, knowledge, opinions and promote the development of collaborative work. Students were enrolled and invited to contribute and participate voluntarily, and it was established that this participation would not be a component of the course evaluation. Under these conditions, student participation was less than 50% of the course, with few contributions (36). A more participatory attitude was expected as six hours/week and intensive in theoretical content. This space was also implemented for 2020-01, which was differentiated by assigning a percentage of the course grade to student participation. The comparison of results showed that the students who participated in 2020-01 doubled the number of students who participated in 2020-02. Likewise, the contributions made on the platform were 976% higher in 202-01 than those made in 2002-02. It can be thought that these differences are because the percentage is constituted in the final grade, as an element more than motivating, persuasive. Based on this result, human actions such as sharing, interacting, “socializing” in a non-face-to-face mode seem to be questioned. One aspect that could be investigated is related to the visibility established when participating in Google Currents © and the attitude that students can assume as each of their contributions is a focus of observation by the academic community of the course.

Fifth discussion

The platforms arranged for autonomous and collaborative work were used by the majority of the students. In the case of the PLEs established in the Symbaloo © platform. However, it was less used; it allowed students to locate certain content and direct their work towards the Google Drive © platform. They used this platform as a repository of information and space to archive collaborative work activities such as synchronous and asynchronous Google Meet © videos and shared the development of documents through Google Docs ©. In structuring the course according to the PBL methodology, a set of tools was established to respond to survey results related to learning preferences. The results showed descending order towards the visual, the reader/writer, and the aural. The above showed a difference with the survey results where preferences were privileged, in descending order, aural, Kinesthetic, Reading/writing, and visual. It may be due to the course dynamics, which, during its development naturally, favored synchronous and asynchronous collaborative work activities through Google Meet ©. It can be inferred that, although the order of preferences seems to change, the aural component is immersed in the Google Meet © videos where conversations and discussions of this learning preference were recorded. In this way, it can be established that the visual was more impacted from the contributions with YouTube videos on the Symbaloo © platform, while the aural was privileged through videos resulting from collaborative work sessions in Goole Meet ©, deposited in the Drive as a repository. With these considerations, the aural component acquires the importance given in the surveys.

On the other hand, the existence of the Kinesthetic component is not observed. The preceding is because the activities were carried out using manufacturing simulation software and were framed in the resolution of specific workshops, with which this requirement was met.

The previous discussions allow to validate or invalidate the hypotheses raised.

Hypothesis 1: The implementation of changes at the technological and curricular level (teaching methods, adjustments in the course program, comprehensive training), pedagogical (forms of evaluation, didactic) allow to develop of the methodology of learning based on problems in a modality of non-face-to-face teaching and favor autonomous learning, collaborative learning and social building of knowledge.

From the technological point of view, the development of the online PBL is favored if there are computers with adequate processing and storage capacity to carry out simulations and specialized programs or other computer applications. Furthermore, the implementation of communication technology was assumed for some students by their families, particularly for the acquisition of internet plans. However, aspects such as the characteristics and technological capabilities of computers, instability, and capacity of the Internet network and cuts in the supply of electricity (not controllable) impacted the development of the PBL Online. Likewise, some students did not have a computer, and the University provided tablets and, in the case of low-income students, who used their mobile phones to communicate, they had the payment subsidized by the University for data plans. However, these devices (tablets, mobile phones) did not allow software, simulators, and, to a low proportion, other applications such as the Microsoft Office © suite. Thus, it is observed that technology hurts the use of the PBL methodology when the conditions mentioned above are not met.

Regarding the curricular modifications, some face-to-face activities were managed in applying the PBL that was developed in person in the Metalworking Processes Workshop course, from 2018-03. Initially, the order of the Syllabus was adjusted so that the theoretical development would be carried out with a sequence more adjusted to the logical sequence of the processes related to the solution of each specific manufacturing problem. For collaborative learning, in addition to the use in semesters before 2020-01, of Google Currents ©, online accompaniment processes were generated for each workgroup, both synchronously and asynchronously, and greater student communication was developed. -Teacher from these consultancies enriched with my experience of more than 20 years at a professional level in industrial manufacturing. Regarding didactics, the use of PowerPoint © presentations continued, but two technological elements were implemented with which it was sought to supplement the use of the board in person. A free license digital board (OpenBoard ©) and a digitizing tablet were used. In this way, it was possible to make specific annotations either on the digital board or already in the presentations, which allowed to complement explanations, theories, expand criteria, etc. Content such as .doc and .pdf files were also used; videos were deposited on YouTube and other resources such as images, Infogrames, etc.

Evaluation: a hybrid process of formative and summative assessment was implemented. Summative evaluation continued with online assessment using the Moodle © platform. For formative assessment, based on the delivery of partial advances according to the PBL methodology, presentations and related support were made via Google Meet ©, and oral type evaluations were carried out, with the corresponding final feedback. A side effect of this hybrid model is that it mitigated the possibility of fraud, as the responses in the different types of assessment had to be consistent—the above, demanding more time for qualification, beyond the teacher's working day.

The preceding allows establishing that from the curricular point of view, for this hypothesis, it is possible to develop the PBL Online methodology, as long as the teacher possesses the required knowledge to be completed with the necessary components. For my particular case, the completion of a Master's Degree in Education with an emphasis on University Teaching, the teaching experience of more than 23 years with this subject, and the professional background of more than 20 years in the practice of engineering allowed

me to have an accumulated knowledge that allowed me to take on the challenges of implementing the PBL Online.

Hypothesis 2: The development and implementation of Personal Learning Environments, including digital educational resources, enables adequate development of problem-based learning in non-face-to-face mode.

The use of personal learning spaces (PLE) was implemented, through a free platform called Symbaloo ©, as a mechanism to favor autonomous learning. Although it was established that its use was voluntary for students, they preferred using other platforms such as Google Drive © to deposit the content related to their autonomous work. If an activity of a personal and individual nature is achieved in these virtual spaces, the important thing is that. The great lesson is that, in crisis scenarios, one should not recommend only one type of help, but that students should be the builders of their learning scenarios, more voluntarily than by demand.

An additional benefit was that in addition to Google Drive © serving as a personal repository as a learning environment, it also served as an interactive role between students in collaborative work scenarios.

All these results show the usefulness of the PLEs for the development of the PLB methodology in non-face-to-face mode.

Hypothesis 3: The personalization of digital educational resources, based on students' learning preferences, promotes learning from problem-solving.

The personalization of digital educational resources, based on students' learning preferences, promoted the processes of learning from problem-solving.

Based on the students' learning preferences using the Kolb and VARK instruments, the personalization of learning resources was structured as follows: From the results of KOLB, a cycle was developed that began with the concrete experience. The importance of this result is that the development of the four stages of the process is consistent with the development phases of the PBL methodology, which was manifested by the interest generated in the students in the search for a solution to the manufacturing problem. . This consistency was the result of the surveys carried out. On the other hand, from the VARK results, different tools associated with preferences were implemented from the visual (videos, PowerPoint © presentations with images), the aural (PowerPoint presentations with videos with audio, multimedia resources, and conversations in processes of synchronous and asynchronous counseling), read-write (Homeworks, readings of specialized books, PowerPoint © presentations with text, development of exercises in interaction with videos and images on the OpenBoard © online board and kinesthetic (Simulators, examples of solution of real problems similar to those posed for the application of the PBL methodology). Finally, it should be mentioned that the differences between the perceptions of student learning according to the VARK model did not favor a particular style, and all were multimodal for all students.

The personalization of digital educational resources, based on students' learning preferences, promoted the processes of learning from problem-solving.

6 Conclusions

- During the development of this thesis, changes were implemented at the curricular level regarding the deployment of the practical component of the course content, emphasizing the implementation of activities such as workshops and interaction through the different virtual platforms used. Likewise, online evaluation processes were carried out with two basic components: the online evaluation and the presentation of the results of the process associated with the solution of a manufacturing problem based on PBL. Likewise, instruments and tools such as electronic boards and digital tablets were implemented to develop interaction in the different synchronous and asynchronous sessions. Similarly, the use of specialized software and simulation software allowed a greater approach to the practical component of

the course. These changes made it possible to develop the learning activity using the problem-based learning methodology in a non-face-to-face mode with the participation of students with autonomous learning and collaborative learning.

- Although an understanding related to the manufacturing processes required to carry out materials transformation activities was achieved, the lack of the practical component manifested with the development of face-to-face laboratory practices is an element that, despite the level of technology That is implemented for virtuality, it will always be necessary due to the interaction that in this type of subject is developed between the students and the specific practice. For example, the sensation of performing a welding process allows the student to experience sensory elements related to the interaction between electrode, part, electrical power system, and person, which is IMPOSSIBLE to develop in the absence of presence. The students manifested these gaps at the end of the course with an express request to generate, after the crisis caused by the pandemic is overcome, spaces for the development of laboratories.
- The non-face-to-face teaching modality, for the case of this thesis, allowed the deployment and implementation of virtual spaces through the use of platforms such as Google Meet ©, Zoom ©, Moodle ©, Google Currents ©, Google Drive (D), Symbaloo ©. The students were expected to use the Symbaloo © platform to structure their virtual learning environments as an instrument to favor autonomous learning. However, the results showed low participation in this space. On the contrary, they were more motivated to use the Google Drive © platform as a repository of the contents of interest and those elaborated by them. This situation could be explained by the fact that a learning process is required to use the Symbaloo © platform, a problem that does not occur with Google Drive © since it is better known and used by them. On the other hand, the use of these spaces was established voluntarily. Despite the preceding, the consolidated use of different personal learning environments shows that autonomous learning processes were privileged and contributed to the development of the PBL in a non-face-to-face mode.
- Freedom of choice of communication and study spaces should be given so that, based on consensus, they provide the confidence and comfort for their use by the students.
- Regarding the digital resources used, it can be mentioned that those that allowed greater interaction between students at the group level and between students and the teacher were the ones that most motivated the search for knowledge related to the solution of an industrial manufacturing problem, based on the PBL methodology. Thus, the Google Meet © spaces for synchronous and non-synchronous sessions allowed this interaction due to the contributions they were able to receive through discussion processes between them and interact with the teacher, enriched by their professional experience in manufacturing and their disciplinary knowledge. Aspects such as online evaluation processes have always generated levels of anxiety and, being highly susceptible to copying, do not allow the knowledge acquired to be evaluated with certainty.
- The performance of evaluations in a hybrid way with an online evaluation component and a synchronous evaluation component through expositions and substantiations of advances related to the solution of the manufacturing problem allowed to establish the coherence of the knowledge and validate the results.
- Although it was sought to personalize digital educational resources, the teacher's demand in time and dedication for their development made this situation complex and perhaps unattainable. However, based on the results of learning preferences, a group-level personalization was carried out, which sought to integrate the interests of all students. In this way, although the personalization of resources is important, it demands time, financial resources, and institutional support, which was not possible to develop in the conjuncture due to COVID19.
- The development of the PBL in a non-face-to-face mode requires greater participation and commitment on the teacher due to the particularities generated by virtuality, content development, didactic aspects, and other related aspects. However, the motivation generated by the teacher in the students is of

fundamental importance so that, in this modality, the students manage to be architects in the creation of their knowledge.

- Just as in a face-to-face way, each student establishes their work rhythm and has a set of particularities that seem to multiply with virtuality. For example, an element of success for this way of working is related to the interaction in synchronous virtual sessions. The generality during the semester and throughout the pandemic has been the difficulty that has been found for students to participate and contribute to synchronous sessions in virtual classrooms n. Experience has shown that this interaction is minimal, and if it does, the protagonists are practically always the same. In this way, the realization of asynchronous sessions allowed this interaction, with an additional effort on the part of the teacher, in time and resources.
- It is not possible to establish study techniques for students to carry out their activities. You can only make suggestions and let them, freely and spontaneously, select the ones that best suit their needs and with which, according to their life history, they have had the most contact.

7 Recommendations

- Develop research projects on students' attitudes towards training in non-contact environments from the point of view of their emotions and motivations. This should make it possible to understand their ways of acting and how they face the learning processes, including emotional factors in the instructional design such as environments, resources, training, and so on.
- Not to lose the experience gained during the pandemic related to non-face-to-face training processes and to consider studying the feasibility of carrying out hybrid activities following the type of subject. Face-to-face part, virtual part.
- Train teachers to develop virtual learning objects and finance the development of specific content for virtual environments from the different components of the curriculum that can be modified.
- Guarantee that the laboratory practices are developed and are face-to-face in post-pandemic scenarios.
- Develop research projects that allow privileging the use of constructivism and connectivism.

8 Bibliography

[1] Ministerio de Salud y Protección Social, «Minsalud,» 06 2020. [En línea]. Available: www.minsalud.gov.co.

[2] Presidencia de la República, «Presidencia de la República,» 2020. [En línea]. Available: https://dapre.presidencia.gov.co/normativa/directivas.

[3] Ministerio de Educación, «MinEducación,» 2020. [En línea]. Available: https://www.mineducacion.gov.co/1759/w3-article-393856.html?_noredirect=1.

[4] Universidad Nacional de Colombia, «rectoria.unal.edu.co,» 2020. [En línea]. Available: http://rectoria.unal.edu.co/index.php?id=9.

[5] UNICEF, «UNICEF para cada niño,» March 2021. [En línea]. Available: https://www.unicef.org/es/comunicados-prensa/escuelas-168-millones-ninos-llevan-casi-ano-entero-cerradas-debido-covid19.

[6] Universidad Nacional de Colombia, «SISTEMA DE INFORMACIÓN NORMATIVA, JURISPRUDENCIAL Y DE CONCEPTOS,» 2020. [En línea]. Available: http://www.legal.unal.edu.co/rlunal/home/doc.jsp?d_i=95361.

[7] Presidencia de la República, «Presidencia de la República,» 2020. [En línea]. Available: https://id.presidencia.gov.co/Paginas/prensa/2020/Gobierno-mantendra-medida-clases-virtuales-trabajo-casa-colegios-universidades-proximo-30-de-julio-covid-19-200519.aspx.

[8] JOHNS HOPKINS UNIVERSITY OF MEDICINE, «JOHNS HOPKINS CORONAVIRUS RESEARCH CENTER,» September 2021. [En línea]. Available: https://coronavirus.jhu.edu/map.html.

[9] M. d. S. y. P. Social, «Minsalud,» 2021. [En línea]. Available: https://minsalud.gov.co/Normatividad_Nuevo/Resoluci%C3%B3n%20No.1315%20de%202021.pdf.

[10] C. Kaparounaki, M. Patsali, V. Mousa, E. Papadopoulou, K. Papadopoulou y K. Fountoulakis, «University students' mental health amidst the COVID-19 quarantine in Greece,» *Psychiatry Research,* 2020.

[11] W. Cao, Z. Fang, G. Hou, M. Man, X. Xu, J. Dong y J. Zheng, «The psychological impact of the COVID-19 epidemic on college students in China,» *Psychiatry Research,* 2020.

[12] N. Ozamiz-Etxebarria, M. Dosil-Santamaria, M. Picaza-Gorrochategui y N. Idoiaga-Mondragon, «Stress, anxiety, and depression levels in the initial stage of the COVID-19 outbreak in a population sample in the northern Spain,» *Cadernos de Saúde Pública,* vol. 36, nº 4, pp. 1-10, 2020.

[13] T. Elmer, K. Mepham y C. Stadtfeld, «Students under lockdown: Assessing change in students' social networks and mental health during the COVID-19 crisis,» 2020.

[14] L. e. a. Liang, «The Effect of COVID-19 on Youth Mental Health,» *Psychiatric Quarterly,* 2020.

[15] P. e. a. Odriozola-González, «Psychological effects of the COVID-19 outbreak and lockdown among students and workers of a Spanish university,» *Psychiatry Research,* 2020.

[16] UNESCO, «UNESCO,» 13 Mayo 2020. [En línea]. Available: www.iesalc.unesco.org.

[17] C. Son, S. Hedge, A. Smith, X. Wang y F. Sasangohar, «Effects of COVID-19 on College Students' Mental Health in the United States: Interview Survey Study,» *Journal of Medical Internet Research,* vol. 22, nº 9, Sep 2020.

[18] M. Savage, R. James, D. Magistro y et al., «Mental health and movement behaviour during the COVID-19 pandemic in UK university students: Prospective cohort study,» *Mental Health and Physical Activity,* vol. 19, October 2020.

[19] M. Browning y et al., «Psychological impacts from COVID-19 among university students: Risk factors across seven states in the United States,» *PLoSONE,* vol. 16, nº 1, pp. 1-27, 2021.

[20] S. Sun, S. Goldberg, D. Lin, S. Qiao y D. Operario, «Psychiatric symptoms, risk, and protective factors among university students in quarantine during the COVID-19 pandemic in China,» *Globalization and Health,* vol. 17, nº 15, January 2021.

[21] N. Cortés Álvarez y et al., «Relación entre la actividad física y la salud mental en estudiantes universitarios en tiempos de pandemia de la COVID-19,» *Jovenes en la Ciencia. Revista de Divulgación de la Ciencia,* vol. 10, 4 August 2021.

[22] UNICEF, «UNICET para cada infancia - América Latina y el Caribe,» UNICEF, [En línea]. Available: https://www.unicef.org/lac/el-impacto-del-covid-19-en-la-salud-mental-de-adolescentes-y-j%C3%B3venes. [Último acceso: Seotiembre 2021].

[23] P. Delgado, «Observatorio - INSTITUTO PARA EL FUTURO DE LA EDUCACIÓN.,» Tecnológico de Monterrey, 20 August 2021. [En línea]. Available: https://observatorio.tec.mx/edu-news/la-crisis-de-salud-mental-en-estudiantes-de-posgrado. [Último acceso: Septembre 2021].

[24] EL TIEMPO, «Salud mental de los estudiantes, una víctima del aislamiento,» *EL TIEMPO,* 5 Junio 2020.

[25] M. Pérez Godoy, «Virtualidad y acceso: el nuevo reto de la educación superior,» *Portafolio,* 24 Abril 2020.

[26] D. Ruka, «Pesquisa Javeriana,» Universidad Javeriana, 04 Mayo 2020. [En línea]. Available: https://www.javeriana.edu.co/pesquisa/educacion-virtual-el-desafio-es-solo-tecnologico/. [Último acceso: Agosto 2020].

[27] Unidad Investigativa - El Tiempo, «Escándalo por garantías falsas al Mintic destapa otro millonario caso,» *El Tiempo,* 8 August 2021.

[28] L. Marciales, «Calidad del internet, el lunar de la educación virtual ante impacto del Covid-19,» *La República,* 16 Marzo 2020.

[29] «cable.co.uk,» [En línea].

[30] L. Torp y S. Sage, EL aprendizaje basado en problemas. Desde el jardín de infantes hasta el final de la escuela secundaria, Buenos Aires: Amorrortu Editores, 1998.

[31] E. De Graaff y A. Kolmos, «Characteristics of Problem Based Learning,» *International Journal of Engineering Education,* vol. 19, nº 5, pp. 657-662, 2003.

[32] D. Travieso Valdés y T. Ortiz Cárdenas, «Aprendizaje basado en problemas y enseñanza por proyectos: alternativas diferentes para enseñar,» *Revista Cubana de Educación Superior,* nº 1, pp. 124-133, 2018.

[33] S. Osses Bustingorry y S. Jaramillo Mora, «Metacognition: a way towards learning how to learn,» *Estudios Pedagógicos,* vol. 34, nº 1, pp. 187-197, 2008.

[34] Deloitte University Press, «Deloitte,» 2017. [En línea]. Available: https://www2.deloitte.com/content/dam/Deloitte/global/Documents/About-Deloitte/central-europe/ce-global-human-capital-trends.pdf.

[35] USB Viterbi School of Engineering, «University of Southern California - Viterbi School of Engineering,» 22 September 2017. [En línea]. Available: https://viterbischool.usc.edu/news/2017/09/hug-the-exponential/.

[36] USC Viterbi - School of Engineering - A Time of Disruption, «University of Southern California,» 2017. [En línea]. Available: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=2ahUKEwiPv-aInOrnAhVKneAKHVoQD40QFjABegQIBRAB&url=https%3A%2F%2Fviterbischool.usc.edu%2Fnews%2F2018%2F02%2Ftime-disruption-batty-bitcoin%2F&usg=AOvVaw1_3uKSO6Pw7Mk695JqAVJf.

[37] C. Tunnermann, B, La educación superior en el umbral del sibglo XXI, Caracas: CRESALC/UNESCO, 1998.

[38] G. Siemens, «elearnspace.org,» 12 December 2004. [En línea]. Available: https://www.academia.edu/2857237/Connectivism_a_learning_theory_for_the_digital_age.

[39] «https://lti.umuc.edu/contentadaptor/topics/byid/ccf4d7a4-7d0f-4c98-8e93-95bd0a7b2879,» [En línea]. Available: https://lti.umuc.edu/contentadaptor/topics/byid/ccf4d7a4-7d0f-4c98-8e93-95bd0a7b2879.

[40] C. Armatas, C. Spratt y A. Vincent, «Putting Connectivist Principles Into Practice: A Case Study of an Online Tertiary Course,» *American Journal of Distance Education,* vol. 28, nº 2, pp. 81-91, 2014.

[41] R. Kop y A. Hill, «Connectivism: Learning theory of the future or vestige of the past?,» *International Review of Research in Open and Distance Learning,* vol. 9, nº 3, pp. 1-13, 2008.

[42] H. Smidt, M. Thornton y K. Abhari, «The Future of Social Learning: A Novel Approach to Connectivism,» de *Proceedings of the 50th Hawaii International Conference on System Sciences | 2017*, 2017.

[43] J. Jalkanen, E. Jokinen y P. Taalas, Edits., Voices of pedagogical development - Expanding, enhancing and exploring higher education language learning, Dublin: Research-publishing.net, 2015.

[44] R. Archee, «Reflections on personal learning environmets: Theory and Practice,» *Procedia - Social and Behavioral Sciences,* nº 55, pp. 419-428, 2012.

[45] N. Dabbagh y A. Kitsantas, «Personal Learning Enviroments, social media, and self regulated learning: A natural formula for connecting fornal and informal learning,» *The Internet and Higher Education,* vol. 15, nº 1, 2012.

[46] G. Veletsianos, Ed., Emerging Technologies in Distance Education, Edmonton: AU Press, 2010, pp. 177-193.

[47] V. Cruz P. y A. Puentes, «Los entornos personales de aprendizaje (PLE) en la enseñanza basada en la resolución de problemas: El uso del e-portafolio,» *EDMETIC,* vol. 2, nº 1, pp. 77-93, 2013.

[48] J. Cabero Almenara, V. Maín Díaz y A. Infante, «Creación de un entorno personal de aprendizaje: Dessarrollo de una experiencia,» *EDUTEC Revista Electrónica de Tecnología Educativa,* nº 38, 2011.

[49] M. Vidal Ledo, G. Martinez Hernandez, N. Nolla Cao y M. Vialart Vidal, «Entornos personales de aprendizaje,» *Revista Cubana de Educacion Medica Superior,* vol. 29, nº 4, January 2015.

[50] D. Boneva y E. Mihova, «3Does,» 2011. [En línea].

[51] N. Chick, «Center for Teaching,» Vanderbilt University, 2020. [En línea]. Available: https://cft.vanderbilt.edu/guides-sub-pages/learning-styles-preferences/. [Último acceso: 2020].

[52] H. Pashler, M. McDaniel, D. Rohrer y R. Bjork, «Learning Styles - Concepts and Evidence,» *Psichological Science in the Public Interest,* vol. 9, nº 3, pp. 105-119, 2009.

[53] S. Cssidy, «earning Styles: An overview of theories, models, and measures,» *Educational Psychology,* vol. 24, nº 419-444, 2004.

[54] M. Healey y A. Jenkins, «Kolb's Experiential Learning Theory and Its Application in Geography in Higher Education,» *Journal of Geography,* nº 99, pp. 185-195, 2000.

[55] D. Kolb, Experiential Learning: Experience as the source of learning and development, Upper Saddle River, NJ: Pearson Education, Inc., 2015.

[56] D. Efstratia, «Experiential education through project based learning,» *Procedia - Social and Behavioral Sciences,* nº 152, pp. 1256-1260, 2014.

[57] K. Morgan, «Problem-based and experiential learning: Engaging students in an undergraduate physical education module,» *The Journal of Hospitality Leisure Sport and Tourism,* vol. 10, nº 1, pp. 128-134, 2011.

[58] A. Kolb y D. Kolb, «Experience Based Learning Systems, LLC,» 2013. [En línea]. [Último acceso: 2021].

[59] N. Fleming y D. Baume, «Learning Styles Again: VARKing up the right tree!,» *Educational Developments,* pp. 4-7, 2006.

[60] B. González, C. Alonso y R. Rangel, «The VARK Model and Design Courses Online,» *Revista Mexicana de Bachillerato a Distancia,* nº 8, pp. 96-103, 2012.

[61] N. Othman y M. Amiruddinb, «Different Perspectives of Learning Styles from VARK Model,» *Procedia Social and Behavioral Sciences,* nº 7(C), pp. 652-660, 2010.

[62] A. Rinekso, «Pros and Cons of Learning Style: an Implication for English Language Teachers,» *Journal of English Language Pedagogy Literature , and Culture,* vol. 6, nº 1, pp. 13-23, 2021.

[63] R. Felder, «OPINION: USES, MISUSES, AND VALIDITY OF LEARNING STYLES,» *Advances in Engineering Education,* vol. 8, nº 1, pp. 1-14, 2020.

[64] C. May, «Scientific American,» 29 MAy 2018. [En línea]. Available: https://www.scientificamerican.com/article/the-problem-with-learning-styles/.

[65] A. Dutson, R. Tood, S. Magleby y C. Sorensen, «A Review of Literature on Teaching Engineering Design Through Project-Oriented Capstone Courses,» *Journal of Engineering Education,* pp. 17-28, 1997.

[66] O. Akinola y B. Ayinla, «An Empirical Study of the Optimum Team Size Requirement in a Collaborative Computer Programming/Learning Environment,» *Journal of Software Engineering and Applications,* nº 7, pp. 1008-1018, 2014.

[67] Ookla (C), Speedtest (C), and Speedtest Intelligence (C) , «SPEEDTEST,» [En línea]. Available: https://www.speedtest.net/global-index. [Último acceso: 2021].

[68] D. Kolb y A. Kolb, «The Kolb Learning Style Inventory 4.0: Guide to Theory, Psychometrics, Research & Applications,» 2013. [En línea]. Available: www.learningfromexperience.com.

[69] M. Svinicki y N. Dixon, «The Kolb Model Modified for Classroom Activities,» *College Teaching,* vol. 35, nº 4, pp. 141-146, October 1987.

[70] E. Flynn, S. Stephens, I. Cunningham y A. Burke, «Experiential Learning, theory and practice: an academic perspective,» 2021.

[71] B. González, C. Alonso y R. Rangel, «El modelo VARK y el diseño de cursos en línea,» *Revista Mexicana de Bachillerato a Distancia,* nº 8, Agosto 2012.

[72] T. Hawk y A. Shah, «Using Learning Style Instruments to Enhance Student Learning,» *Decision Sciences Journal of Innovative Education,* vol. 5, nº 1, pp. 1-19, 2007.

[73] F. Díaz Díaz y A. Castro Arévalo, «Requerimientos pedagógicos para un ambiente virtual de aprendizaje,» *Cofín,* vol. 11, nº 1, 2017.

[74] Portafolio, «Así está Colombia en cuanto a accesos a internet fijo y móvil,» 21 July 2021. [En línea]. Available: https://www.portafolio.co/economia/infraestructura/conexiones-a-internet-fija-y-movil-que-hay-en-colombia-segun-mintic-554259.

[75] COMUNICAN S.A., «La historia del escándalo del Mintic, Karen Abudinen y Centros Poblados,» *El Espectador,* 9 Septiembre 2021.

[76] Departamento Administrativo Nacional de Estadística – DANE, «Boletín Técnico - Gran Encuesta Integrada de Hogares,» 2021.

[77] M. Sankey y M. Gardiner, «Engaging students through multimodal learning environments: The journey continues,» de *Proceedings ascilite Sydney 2010*, Sydney, 2010.

[78] UNICEF, «Unicef,» 2020. [En línea]. Available: https://www.unicef.org/es/historias/como-contempla-vuelta-escuela-durante-pandemia-covid19.

[79] Johns Hopkins University, «Johns Hopkins University and Medicine,» 2020. [En línea]. Available: https://coronavirus.jhu.edu/data/new-cases.

[80] L. Crocker, W. Heller, S. Warren, A. O´Hare, Z. Infantolino y G. Miller, «Relationships among cognition, emotion, and motivation: implications for intervention and neuroplasticity in psychopathology,» *Frontiers in Human Neuroscience,* vol. 7, nº 261, pp. 1-19, 2013.

[81] Merriam-Webster, «Merriam-Webster,» 2020. [En línea]. Available: https://www.merriam-webster.com/dictionary/emotion.

[82] G. Bourdin, «Anthropology of the emotions: concepts and trends,» *Cuicuilco,* vol. 23, nº 67, pp. 55-74, 2016.

[83] R. West, «EdTech Books,» 2018. [En línea]. Available: https://edtechbooks.org/lidtfoundations.

[84] International Academy of Education - International Bureau of Education, «International Academy of Education,» 2014. [En línea]. Available: http://www.iaoed.org/index.php/ed-practices-series.

[85] Centre for Educational Research and Innovation -OCDE, «OCDEiLIbrary,» [En línea]. Available: www.oecd.org/edu/ceri/50300814.pdf.

[86] A. Faria, A. Almeida y C. Martins, «Emotion Effects on Online Learning,» de *Intelligent Distributed Computing IX*, 2016.

[87] P. Bamidis, «Affective Learning: Principles, Technologies, Practice,» de *Brain Function Assessment in Learning*, Patras - Greece, 2017.

[88] IGI Global , «IGI Global. Publisher of Timely Knowledge,» 2020. [En línea]. Available: https://www.igi-global.com/dictionary/learning-design-quality/791.

[89] S. Gano-Phillips, «Affective Learning in General Education,» *Journal of General and Liberal Education,* vol. 6th Issue, pp. 1-45, 2010.

[90] S. Osses Bustingorry y S. Jaramillo Mora, «Metacognition: a way towards learning how to learn,» *Estudios Pedagógicos,* vol. 34, nº 1, pp. 187-197, 2008.

[91] Alhana Binti Othman, Mohamad Ishak Bin Mohamad Ibrahim, Izzatul Ussna Binti Ridzwan y Norlaila Mazura Binti Mohaiyadin, «FACTORS CONTRIBUTE TOWARDS CHALLENGES FACED BY THE STUDENTS IN THE IMPLEMENTATION OF PROBLEM BASED LEARNING (PBL),» *Journal of Education and Social Sciences,* vol. 4, pp. 133-139, June 2016.

[92] R. Hernández Sampieri, C. Fernández Collado y P. Baptista Lucio, Metodología de la Investigación, McGraw Hill, 2014.

[93] UNIVERSIDAD NACIONAL DE COLOMBIA, «SISTEMA DE INFORMACIÓN NORMATIVA, JURISPRUDENCIAL Y DE CONCEPTOS "RÉGIMEN LEGAL",» 2021. [En línea]. Available: http://www.legal.unal.edu.co/rlunal/home/doc.jsp?d_i=95609.

[94] UNIVERSIDAD NACIONAL DE COLOMBIA, «SISTEMA DE INFORMACIÓN NORMATIVA, JURISPRUDENCIAL Y DE CONCEPTOS "RÉGIMEN LEGAL",» 2021. [En línea]. Available: http://www.legal.unal.edu.co/rlunal/home/doc.jsp?d_i=97347.

[95] M. d. E. Nacional, «MinEducación,» 2021. [En línea]. Available: https://www.mineducacion.gov.co/1759/w3-propertyvalue-67454.html?_noredirect=1.