Teaching-Learning in the Industrial Engineering Career in Times of COVID-19

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Abstract. Since cancellation of face-to-face education during the health emergency caused by COVID-19, higher education institutions, have had to guarantee the right to education through virtualization. Therefore, this work analyzes the teaching-learning process adapted to the virtual mode in the students of technical subjects of the professionalizing axis in the industrial engineering career a private university of Ecuador. Quantitative research is performed for this using surveys, performance index collection, and historical data. The method has a comparative scope between two academic periods, contrasting the data before and after the pandemic, the indicators are taken from students and teachers. The analysis of surveys is carried out in 3 components of teaching, in students are obtained: planning and methodology, with 81.1% considered as satisfied; teacher-assisted activities, with 79.1% content with the activities; and in practical activities, with 74.9% according to the tools used. Comparisons of indicators in different academic periods show minimal variations in performance, teachers improve the average performance score by 4.1%, and students drop academic performance by 2.6%. Finally, the correlation demonstrates a similar perception between students and teacher in the learning practice component.

Keywords: Teaching-learning · Higher education · Virtual education · Teacher performance index · COVID-19

1 Introduction

In December 2019, an outbreak of viral pneumonia began in the city of Wuhan, associated with a new coronavirus, which was initially a local outbreak; it has become a global pandemic with catastrophic consequences. In February 2020, an official taxonomic name was established for the new SARS-CoV-2 virus, and the disease it causes, Coronavirus Disease 2019 (COVID-19) [1]. The virus has now infected more than five

P. Zaphiris and A. Ioannou (Eds.): HCII 2021, LNCS 12784, pp. 517–530, 2021.
https://doi.org/10.1007/978-3-030-77889-7_36

million people and caused the deaths of 350000 worldwide, so most countries stop their face-to-face activities to work remotely or online [2], forcing deep rethinking of the way of life.

The Covid-19 pandemic is a major disaster experienced by almost every country in the world, impacting on all the lifelines of each country; one of the sectors that have been affected is education, aside from governments' efforts to solve the consequences of COVID- 19, they must continue keep the stability and sustainability of the learning process that is the right of all citizens [3]. Because of the pandemic, the entire education system has switched from traditional teaching methods to online learning systems around the world. COVID-19 reinforces the need to explore new learning opportunities [4].

In the field of higher education, the transformation from conventional classes to a virtual format was immediate [5] which has forced the "traditional" education system to migrate to a more dynamic and connected system where the training process is carried out in an assisted and/or remote way [6]. Digital technology becomes an integral part of life, and also essential for connectivity and communication at all levels [7]. Based on the "new reality" facing the world, educational institutions, through online platforms, offered a solution to continue teaching and learning activities by trying to ensure an effective flow of communication between teachers and students; sessions tend to run slower because breaks are required to allow time for people to speak and others to understand, posing an increased risk that students will be easily distracted, that is why the teacher plays a fundamental role because in order to keep students engaged longer, they require preparing more resources [8] which led to a real challenge since they have found the need to "learn by doing", to imitate face-to-face teaching [9]. In this scenario, they continue their academic activities adapting to non-face-to-face formats through different digital platforms [10] that involve the use of virtual classrooms, applications, devices and software that, despite social distancing, communicate us interactively with the world [11].

In Latin American countries, the difficulties of this challenge are increased by socio-economic inequalities, with the consequent digital gaps of both students and teachers [12] as specific resources, skills and competencies are required that are not necessarily owned by each party. Teacher's activity is linked to the pedagogical use of digital technologies, as well as creativity to solve different challenges of the context that allow to develop creative and autonomous learning by the student [13].

According to [14], online education has great advantages as any videoconference must be recorded and socialized for later use, as a source of consultation and support for students. However, there are also disadvantages, one of them the fact that not all students have handy electronic devices and/or internet, which makes it difficult to attend classes and, therefore, their level of learning is reduced.

In [15], it is clear that there are basically three gaps affecting the quality of learning and teaching processes in COVID-19 times due to factors that affect both learning and professional performance through online education. The first gap relates to access to technological means or devices, the second to the efficient use of technology, and the third relates to school capacity, i.e., teacher skills, the availability of online resources to support teaching at all levels.

As [12] points out, the diversity of realities in which the virtual teaching-learning process takes place makes it difficult to propose a standardized communication strategy. The selection of communication channels depends on the technological resources that students have in their homes (devices and internet connectivity), the educational stage and the digital skills of teachers and students.

Undoubtedly, one of the concerns of educational institutions is to find the appropriate method for teaching subjects that require face-to-face practicums to strengthen knowledge. The experimental component presents major challenges for its implementation [16]. One of the branches related to practical education is engineering; due to this global emergency, teachers have found the need to look for tools that allow students to solve problems without carrying out practical face-to-face activities, through case studies, applications, use of simulators, necessary to understand the different processes and further develop their capacity for autonomous and critical thinking [17].

This article sets out the perspective of both teachers and students regarding the teaching-learning process of the subjects in the area of management of productive systems, of the face-to-face mode of the Industrial Engineering career, in order to analyze the level of acceptance of virtual learning during the first partial, of the first half of 2020 (academic period A20), with regard to the face-to-face teaching of the first part, of the second half of 2019 (academic period B19); in this way conclusions can be drawn on the impact of virtual classes in the area of management of productive systems. This article is divided into several sections: introduction, where the problem is contextualized and justified; the method used to obtain the relevant data for research; the results obtained, as well as the conclusions.

2 Methodology

2.1 Research Design

This study is a quantitative research, and its scope is comparative, as an analysis of the results obtained from 187 surveys applied to students who have classes of the subjects of the professionalizing axis in the industrial engineering career is carried out. The surveys were also applied to 21 teachers who teach subjects in this area. In addition, teacher and student performance rates are used to compare them in two different academic periods, before and after the onset of COVID-19. Teaching performance is evaluated from the perspective of the student, who complete a comprehensive assessment to the teacher that measures the level of conformity of students with teaching performance, this quantification is performed in all academic periods to feedback the performance of the teachers. Student performance is obtained from grades generated during the study period, obviously assigned by teachers. These scores are also attained from an earlier academic period, when still working in face-to-face mode.

Figure 1 presents the methodology used for teaching-learning analysis, the data to be collected in different ways; the questionnaire is completed using a Likert scale that allows to measure the perception of teachers and students in three academic components. A teacher evaluation is also applied by measuring student satisfaction with teaching in 6 technical subjects. Regarding learning, students are assessed. In addition, historical pre-pandemic data are used in relation to teacher evaluation and student assessment, with the aim of comparing the data in different circumstances. In addition, a correlation analysis is carried out between the responses of teachers and students to the developed questionnaire, with the purpose of contrasting these different perspectives.

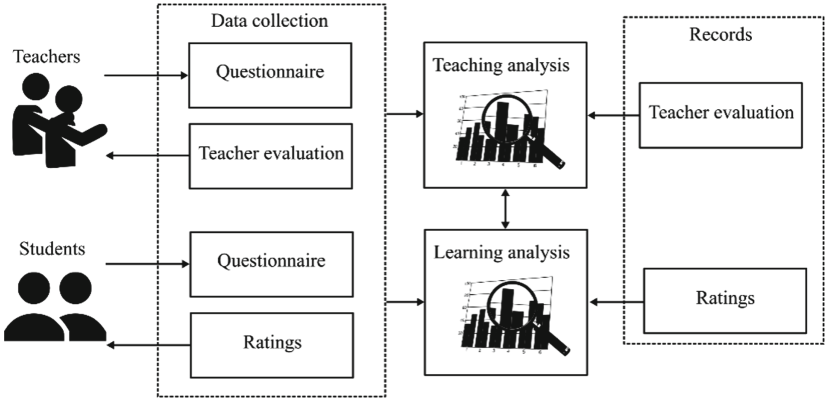

Fig. 1. Methodology for the analysis of teaching-learning in the industrial engineering career.

2.2 Surveys

A survey of 7 questions is prepared in Google Forms, using closed questions divided into three components: 1. Planning and methodology (3 questions); 2. Teacher-assisted activities (2 questions); 3. Practical activities (2 questions), to obtain accurate information about each of them. Each of the questions has four options (never – on occasion – almost always – always). In order to give validity and reliability to the questions posed, they are subject to expert judgement in order to verify their correct approach. The analysis uses the data visualization technique for which graphs are made to detect behaviors and make comparisons with respect to the data obtained, using Excel. Table 1 presents the questions applied to the 187 students and the 21 teachers of the Industrial Engineering career, of the professionalizing axis.

Table 1. Survey questions by components (C).

C	Question
Planning and methodology	-Do you consider that the methodology and planning of the formative projects of the professionalizing axis taught in virtual mode are appropriate to meet the objectives and contents?
	-Do you consider that the contents of the formative projects of the professionalizing axis have been adapted according to the training needs in the virtual mode of education?
	- Do you consider that during classes in the virtual mode of the formative projects of the professionalizing axis, additional teaching resources such as videos, glossaries, presentations that allow to strengthen learning have been used?
Teacher-assisted activities	- Do you consider that the exercises and/or case studies developed during the classes in the virtual mode have been adequate and sufficient for a better understanding of the contents of the formative projects of the professionalizing axis?
	- Do you consider that both individual and collaborative learning has been encouraged during classes in the virtual modality of the training projects of the professionalizing axis?
Practical activities	- Do you consider that the practical implementation and experimentation activities (PAE) developed during classes in the virtual mode have been adequate and sufficient for a better understanding of the contents of the formative projects of the professionalizing axis area?
	- Have simulators been used to carry out practical application and experimentation activities (PAE) during classes in the virtual mode of the formative projects of the professionalizing axis area?

2.3 Assessments and Historical Data

Each academic period (comprises 5 months) an evaluation is carried out to each teacher which is performed by students and authorities of the Industrial Engineering career, in which a percentage of compliance is assigned to the different activities that must be carried out independently or together; for this case, the evaluations of academic periods will be analyzed: B19 (September 2019 to February 2020, which was face-to-face) and the A20 (April–August 2020, which was virtual). Considering that information will be collected only from teachers who teach the subjects corresponding to the professionalizing axis, with the aim of analyzing the information to see if there is an impact within face-to-face education vs. virtual. Table 2 shows the percentage out of 100% of the outcome of evaluations to teachers in the B19 and A20 periods.

Table 2. Summary of teaching evaluation.

Teacher code	B19	A20	Teacher code	B19	A20
DCII – ACMI	96,4%	100,0%	DCII – ORER	96,6%	96,0%
DCII – CMLE	97,4%	98,8%	DCII – PGDJ	90,4%	90,5%
DCII – CVJS	90,6%	95,2%	DCII – RMMB	96,2%	92,0%
DCII – CNLG	92,2%	98,0%	DCII – STFD	97,2%	97,2%
DCII – CAME	92,2%	65,2%	DCII – SAEL	88,0%	92,0%
DCII – EPCA	96,6%	97,2%	DCII – SDPE	93,8%	98,4%
DCII – FPEM	91,0%	97,4%	DCII – TIME	88,4%	98,6%
DCII – LCAR	97,4%	96,4%	DCII – VAJL	96,0%	99,2%
DCII – MMVH	93,2%	95,4%	DCII – VCCS	88,6%	90,0%
DCII – MVSP	94,4%	90,8%	DCII – VPDA	83,6%	94,8%
DCII – NMOM	90,2%	95,2%			

Then, a history of the average of grades obtained by students in the subjects belonging to the professionalizing axis was made, whose average is out of 5 points (Table 3). These grades correspond to the academic periods B19, which was developed in person, and A20, that was executed virtually due to the "new reality".

Table 3. Average student grades.

Subject	Period B19	Period A20
Programming	4,2	3,6
Work Design and Measurement	3,4	4,6
Method Engineering	4,1	4,3
Operational Research	4,3	4,0
Production Planning and Control	3,7	4,1
Operations Management	4,1	3,9
Production Management	4,1	4,1
Plant Design and New Products	3,5	3,7
Operations Management	4,1	4,5

2.4 Participants

Surveys are conducted to students who are enrolled in the subjects of the area of management of productive systems and to the teachers who teach them. In reference to teachers, it is important to clarify that of the 21 teachers surveyed 3 are hired part-time (TP) 12 hours per week, and 18 are hired full-time (TC) 40 hours per week (8 hours per day). With regard to the ethical standards of this research for data collection, it is important to note that the respective authorization is available by the career authorities to be able to conduct the surveys of both teachers and students with their informed consent. The number of respondents, as well as the evaluated subjects can be observed in Table 4.

Table 4. Participants' Demography - Male (M) and Female (F).

Subjects	Level	Teachers			Students		
		M	F	Age Average	M	F	Age Average
Programming	3	2	1	36	25	1	20
Work Design and Measurement	4	2	0	42	19	5	20
Method Engineering	5	2	0	40	27	1	21
Operational Research	5	2	1	40	27	1	22
Production Planning and Control	6	1	1	42	13	1	22
Operations Management	7	2	1	42	9	3	23
Production Management	8	1	1	40	11	2	23
Plant Design and New Products	9	1	1	37	19	2	24
Operations Management	9	1	1	36	19	2	24
Total		**14**	7		**169**	**18**	

3 Results

3.1 Student and Teacher Surveys

Table 5 shows an overall average of the results obtained in the surveys applied to students, within the planning and methodology component where the planning used to teach is analyzed, if the contents are according to the needs of the environment and if the teaching resources such as videos, infographics, glossaries allow to strengthen the learning. There is a 46.5% for almost always. The other component is teacher-assisted activities, which examine the different case studies applied in the classes, autonomous and collaborative work, resulting in 40.9% for almost always. Finally, the practical activities component, whose study corresponds to the tasks where simulators are used, with 42.8% for almost always.

Table 5. Student survey results.

	Planning and methodology component	Teacher-assisted activities component	Practical activities component
Never	2.9%	2.1%	4.3%
On occasion	16.0%	18.7%	20.9%
Almost always	46.5%	40.9%	42.8%
Always	34.6%	38.2%	32.1%

Table 6 indicates the average percentage of surveys applied to teachers in the Industrial Engineering career who teach in the subjects of the professionalization axis. As for the planning and methodology component, 58.7% believe that they always allow learning objectives to be achieved. Regarding assisted activities, 66.7% state that they always help to understand the contents. And 50.0% believe that practical activities almost always contribute to virtual learning.

Table 6. Teacher survey results.

	Planning and methodology component	Teacher-assisted activities component	Practical activities component
Never	.0%	.0%	.0%
On occasion	4.8%	.0%	9.5%
Almost always	36.5%	33.3%	50.0%
Always	58.7%	66.7%	40.5%

3.2 Assessments of Students and Teachers

Figure 2 shows the percentage comparison of the teacher evaluation carried out before and after the “new reality”.

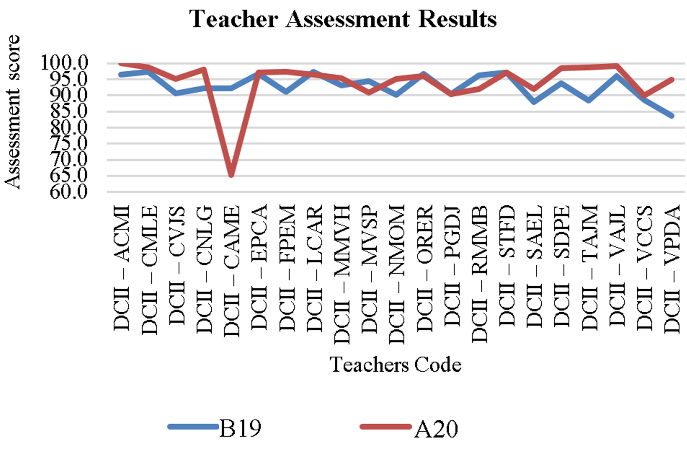

Fig. 2. Result of teacher evaluations in periods B19 and A20.

Figure 3 presents the averages of students’ grades in face-to-face mode. Figure a shows the comparison between the periods detailed in the method, contrasting the grades before and after the “new reality”. Minimal differences are visible, which are backed up by an average error of 2.6% between both data.

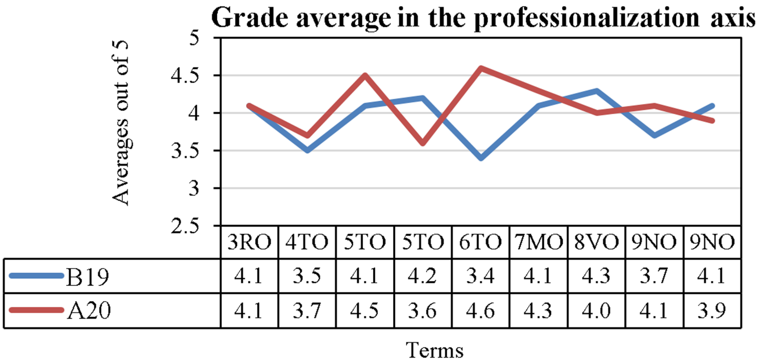

Fig. 3. Average number of student grades in the subjects of the teaching axis.

3.3 Comparison of Scores for Students and Teachers

Box and whiskers plots are used to compare performance and performance results in students and teachers, analyzing the central trend and the distribution of values. Figure 4 presents the graph of student grades in academic analysis periods with the aim of analyzing learning data; period B19 has an average of 4.1/5 and a standard deviation of 0.32, and the A20 period has an average of 4.1/5 and a standard deviation of 0.34. Although the mean remains for both data groups, and the deviation varies minimally, the quartiles of the period in virtual mode are shifted upwards, showing symmetrical quartiles and a small improvement in grades in some cases.

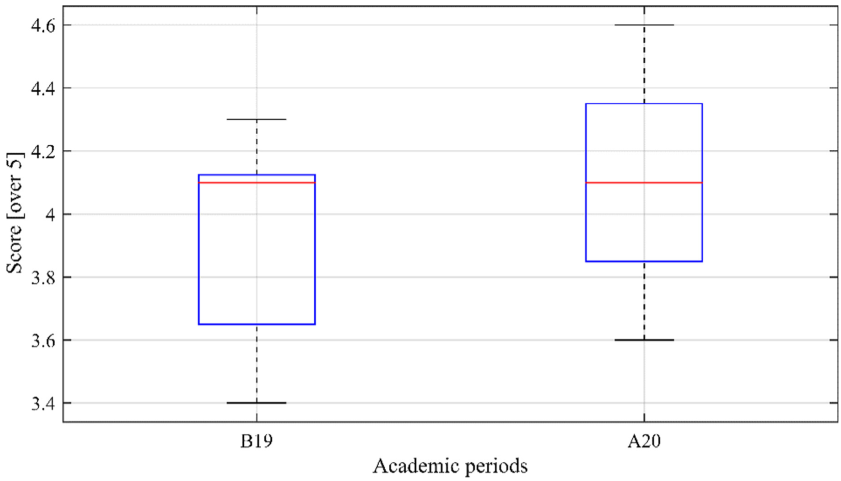

Fig. 4. Box and whiskers plots for students' grades in 2 academic periods.

Regarding the teaching analysis, Fig. 5 shows the box and whiskers plots of the teacher performance indicator in the academic periods studied (discarding the case of score lower than 70%). In the period B19 there is an average mark of 93.2% with a standard deviation of 3.84% and in the A20 period an average of 96% with a standard deviation of 3.01%. These results show an improvement in teachers' assessments for the period in virtual mode, increasing the scores obtained and reducing the dispersion of the values. In general, it is notorious that both teachers and students improve scores in the new mode of study.

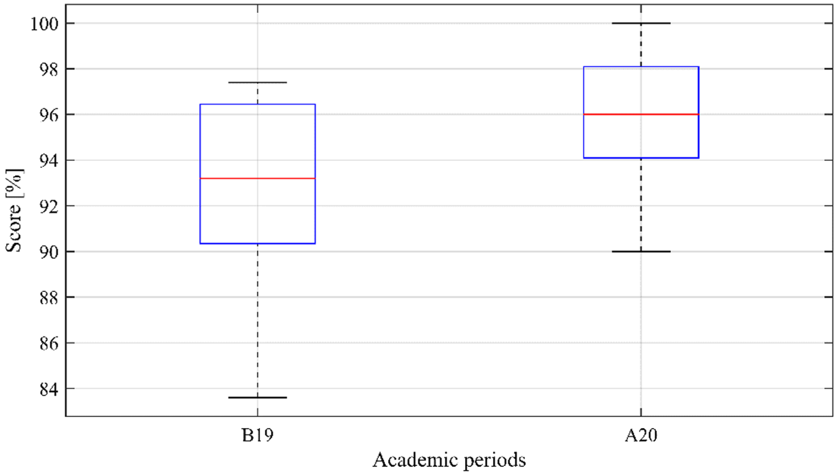

Fig. 5. Box and whiskers plots for the performance of teachers in 2 academic periods.

3.4 Correlation of Student and Teacher Surveys

Figure 6 shows the differences in the criteria with respect to the methodological field of the learning teaching process in the virtual mode, so that teachers show a mostly positive current in the assessment ranges, while students present a small percentage that considers that methodology and planning is not adequate or has not migrated optimally to virtuality, when the analysis of the relationship that the two variables have with each other was performed, a r = 0.811 was obtained which for our interpretation means that both the responses of teachers and students maintain a relationship with each other, especially in the ranges of almost always and always.

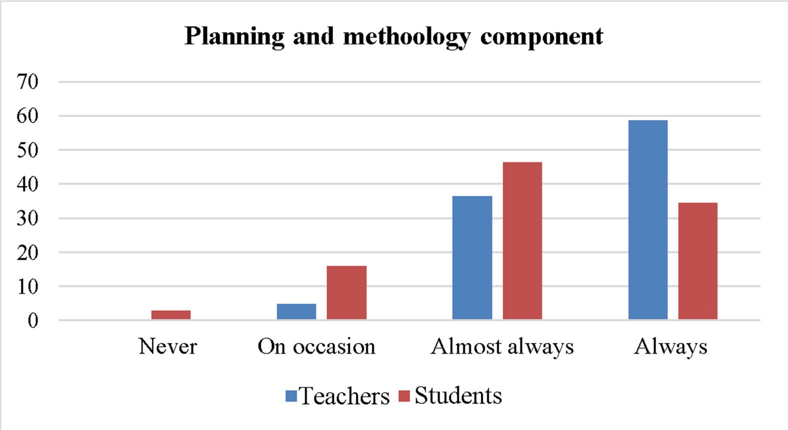

Fig. 6. Relationship of the planning and methodology component.

With regard to the component of teacher-assisted activities, presented in Fig. 7, it can be commented that students, in a percentage of approximately 20%, consider the activities carried out with the teacher have been inadequate or insufficient, although a large majority, approximately 40%, consider that almost always the activities are adequate, however the correlation of these does not exceed an r = 0.811 which indicates that the variables are related but not in a linear way. It is worth highlighting, above all, the perception of teachers regarding this component especially in what corresponds to always.

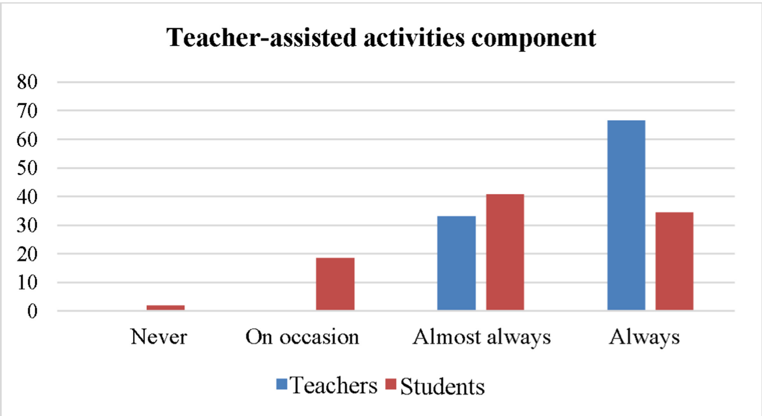

Fig. 7. Relationship of the component teacher-assisted activities.

The component of the practical activities presented in Fig. 8 shows the best correlation with the variables used, with a r = 0.958 based mainly on responses by students in which 96% of students consider that the virtual applications, simulators, and tools used for the development of the practical component, is relevant and provides knowledge and skills that contribute to vocational training.

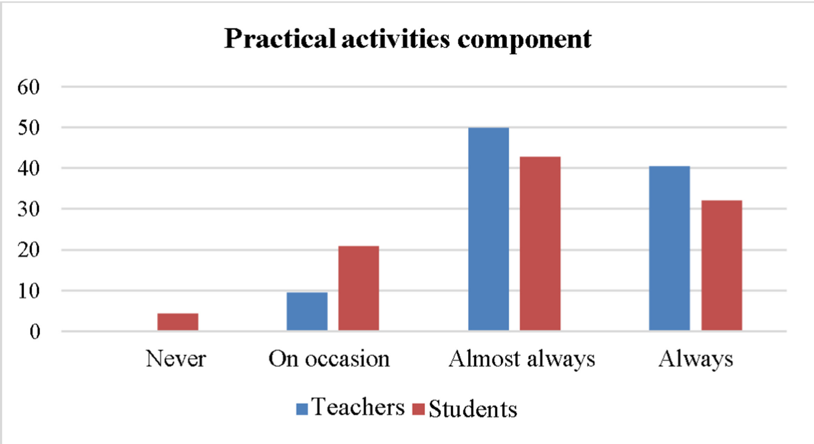

Fig. 8. Relationship of the practical activities component.

4 Conclusions

This research performs the learning analysis in university students who take subjects linked to the area of management of productive systems in the Industrial Engineering career, for this, surveys were applied to students and teachers, investigating the components of planning and methodology, assisted and practical activities. The results indicate that 43.4% of students almost always achieve learning outcomes in the new mode of study. For teachers, 55.3% indicates that learning results are always achieved. In addition, grades are compared before and after adopting the virtual mode to carry out the learning-teaching process, showing slight changes because of the new study scenarios.

In the process of bibliographic review carried out for the preparation of this document, the small number of studies related to the scope of development of this research is evident; this directly related to the atypical situation that the world is going through and therefore, mandatory migration to virtual environments caused by the confinement of the pandemic by COVID 19.

Depending on the results generated in this job, the following relationships can be established. There is no total satisfaction on part of students with the tools and resources used for the development of the learning teaching process used in the new mode of study, while, on the other hand, teachers consider that the methodology used is adequate to develop the critical and cognitive skills of the student. With regard to the differences in grades, they are typical of the process of adapting to a new study environment so they are not considered as representative data to define a sudden and entirely negative effect for the virtual mode and the new reality.

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