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Virtual education in university teaching. Application of the TPACK model in quantitative subjects

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Abstract

Purpose: To analyse the impact of the compulsory adaptation of teaching brought about by Covid-19 in quantitative subjects, taking into account the technological, pedagogical and content-related aspects of the TPACK model.

Design/methodology: A structured questionnaire with differentiated blocks with closed and open-ended questions is applied. The data collected from 215 students are analysed descriptively and inferentially using Student's t-test. Sentiment analysis is carried out on the text collected from the survey's open-ended questions.

Findings: By applying e-learning under the TPACK model, lessons are redesigned in a way that encourages participation and follow-up. From the results of the survey carried out with students with a face-to-face profile, the positive assessment of the method and the tools used stand out.

Practical implications: The use of technological tools and, above all, how they are introduced in the classroom improves student acceptance, thereby reducing the probability of students dropping out, especially among those with a strong face-to-face profile.

Originality/value: This evidence-based research offers to address the shortage of conceptual models suitable for teacher training, not only in technology and its use but also in how to apply it effectively, including the knowledge, skills and abilities needed to implement it.

Keywords: e-learning, TPACK model, University teaching, Technology, Sentiment analysis

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1. Introduction

The crisis generated by Covid-19 prompted society as a whole to rethink the way it acts. Among the sectors most affected is the education sector, which has been structurally forced to react without material time to train adequately and sometimes without even having the necessary resources (Aznar Sala, 2020; Cortés-Rojas, 2021). Teachers need to rethink how they teach and the resources they use, and students need to rethink how they access information, and continue to learn.

It is no overstatement to say that this shift towards remote, and later hybrid, teaching removes all the pillars of the system, sometimes revealing both the lack of physical resources and the poor training of many teachers, many of whom lack the necessary and adequate digital skills. As a result of all this, there is no shortage of research that deals with the consequences of this educational shift at different levels and from different points of view (Dorfsman & Horenczyk, 2021; García-Peñalvo, 2021; Guerrero & Matute, 2021; Pérez-López, Atochero & Rivero, 2021). For teachers, it is a matter of long hours of hurried training and challenging work, at times generating anxiety and stress (Cortés-Rojas, 2021). It also represents an abrupt change for the students, one that is neither expected nor desired, especially for those with a markedly face-to-face profile, who are not used to working individually or with new and unfamiliar materials, but who are more accustomed to social contact with their classmates and with the teacher.

The new situation, therefore, forced schools, teachers and, of course, students to look for immediate solutions. A need for total change was required due to the circumstances, without having the time to think calmly, to reconsider, to be able to stop and evaluate alternatives or to try out the best options for each situation. It is necessary to rethink the teaching methodology to be applied (Pérez-López et al., 2021), introduce e-learning in contexts where it was not used before (García-Peñalvo, 2021), reformulate training activities and assessment systems (Castillo-Olivares & Castillo Olivares, 2021; García-Peñalvo, Corell, Abella-García & Grande, 2020), all without modifying the objectives. In other words, by the end of the course, students should achieve the programmed competencies and develop, without problems, the learning outcomes foreseen for face-to-face teaching, even if they do so remotely.

The educational community then takes on a double challenge: on the one hand, to ensure that students do not become demotivated and fall behind (Bakhronova, 2021), while ensuring that, in a very short period of time, they are able to change their way of learning, replacing physical contact with their teacher with a virtual learning system where the intermediary is a screen (Pérez-López et al., 2021). And on the other hand, to achieve that which motivates most in a classroom, which is to feel that the teacher is understood, listened to, interested, motivated and therefore learns, is not suddenly replaced by simple e-mails with attachments, or PDFs with content and more content accompanied by links to Internet resources. To this end, it is not enough to simply resort to teaching in a quasi-emergency model, but it is necessary to plan and evaluate it from a curricular point of view (Hodges, Moore, Lockee, Trust & Bond, 2020). In short, to achieve real change with real tools that make this task possible.

The question on which this research is based seeks to analyse whether a new way of teaching/learning allows for the interaction between the model's different dimensions: technological, pedagogical and content when applied to a virtual learning environment.

To this end, the aim of this study, based on empirical evidence, is twofold. On the one hand, to analyse how the change from face-to-face university teaching to online teaching has been carried out in quantitative subjects, taking into account the premises of the TPACK model. On the other hand, the aim has been to study the perception of university students participating in the adjustment from face-to-face teaching to compulsory remote teaching, analysing the didactic strategies carried out by the teaching staff with the intention of optimising student performance, continuing with their learning and trying to minimise the possible risk of students dropping out of the course (this research work arose as a result of the COVID-19 MENTION award obtained by the authors, members of the Making Connections Teaching Innovation Group. Creativity, Innovation and Neurodidactics at the 7th Conference on Educational Innovation at the URJC).

2. Literature review

The situation described above has accelerated the technological change that has been taking place for some time throughout the world, as well as in Spain, which, with regard to education, includes various action plans, among which is the plan to improve digital competence promoted by the National Institute of Educational Technologies and Teacher Training of the Ministry of Education and Vocational Training. However, technology alone is useless if there is no pedagogical intention to back it up (Gómez- Gómez, 2021). In other words, the importance of introducing technology into education is obvious, but the correct way to implement it must not be neglected. This idea is explored by Cabero-Almenara, Marín-Díaz and Castaño-Garrido (2015), who in turn discovered the scarcity of conceptual models suitable for teacher training, not only in technology, but also in how to apply it effectively, with the knowledge, skills, abilities and resources necessary to do so.

It is mainly for this reason that the TPACK model, which stands for Technological Pedagogical Content Knowledge, was developed between 2006 and 2009 by Koehler and Misha (Koehler & Mishra, 2009; Mishra & Koehler, 2008; Rosenberg & Koehler, 2015). They reflect on the different skills that teachers need to have in order to incorporate technology effectively. Hence, their main purpose is to see the most appropriate and effective way of integrating technology into the classroom if student learning is to be optimised. To do this, teachers need to develop 3 types of knowledge: technological (how the tools they want to use work, and in what context they can be used), pedagogical (how to teach effectively) and, of course, knowledge of the content of what they want to teach. It is only through the interaction of these three perspectives that technology can be effectively integrated into the classroom. Khoeler and Misha (2009) illustrate this in Figure 1 below.
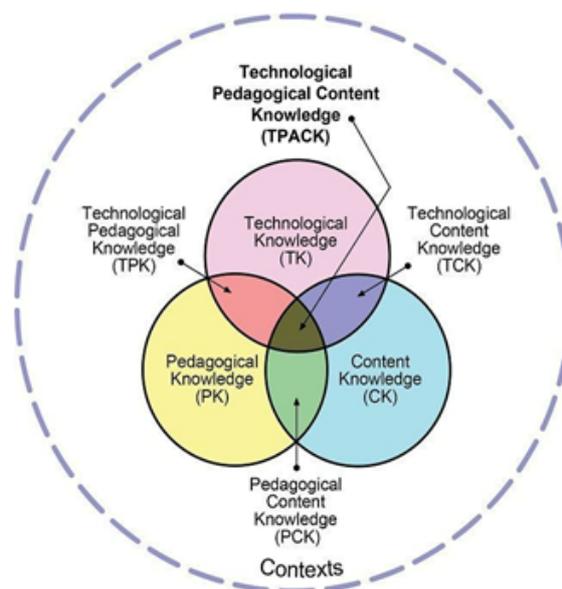

Figure 1. TPACK Model and its
components (Koehler & Mishra, 2009)

As reflected in the figure above, the model does not stop there. As its final proposal is for a teacher to be able to effectively incorporate technology into the classroom, these three components cannot be presented on their own, but need to work together. The most eneral: CK: Knowledge on the subject; PK: Pedagogical knowledge and CT: Technological knowledge, with other knowledge (PCK: Pedagogical Content Knowledge; TCK: Knowledge of the use of technologies; TPK: Technological pedagogical knowledge, finally arriving at TPACK: Technological and Pedagogical Knowledge as well as Knowledge on the Subject (Cabero-Almenara et al., 2015). These same authors (p. 14), clarify each of these concepts, drawing on the ideas of Jimoyiannis (2010) and Schmidt, Baran, Thompson, Mishra, Koehler and Shin (2009):

- Pedagogical Knowledge (PK): this refers to the teacher's knowledge of the pedagogical activities that can be used, the processes and practices of the method used, educational theories, learning assessment, and how they relate to educational purposes. They can be used with any content, and can also include motivational strategies, as well as a variety of different active activities and methodologies.

- Content Knowledge (CK): that which teachers have on the subject to be taught, and which is independent of the pedagogical activities and strategies to be used.

- Technological Knowledge (TK): regarding the different technological tools to be used in their professional activity.

- Pedagogical and Content Knowledge (PCK): This allows them to know how to make the content more understandable for their students. It is already set in a particular area of knowledge and is therefore different in one area from another. It allows the teacher to discern what is easy or difficult for the student to learn.

- Technological and Content Knowledge (TCK): It suggests how to represent concepts with technology and how such media can be used to create media representations for specific content. It is independent of its pedagogical use.

- Technological Pedagogical Knowledge (TPK): This model refers to the knowledge of pedagogical activities that a teacher can do using different technologies, i.e. the knowledge of technological tools that can be used in teaching, changing the way teachers teach, on the one hand, and motivating and involving students in learning, on the other.

- Technological pedagogical knowledge of the content (TPACK): When the 3 components are brought together. Cabero-Almenara et al. (2015) define it as "didactic content knowledge, referring to the knowledge required by teachers to integrate technology into their teaching in any content area" (p. 15).

Curiously, TPACK, which is still little known among many teachers, has been the subject of extensive literature from the very beginning. The article by Rosemberg and Khoeler (2015) is an interesting read. They carry out a systematic review of the specialised literature regarding this model, linking the results of the interaction of this model with the context in which it is produced.

Likewise, its knowledge and application not only enhance the profile and professional development of teachers, but also have an impact on the design of training proposals and academic programmes that are developed with the intervention of technology, both in virtual learning environments and in different forms of non-classroom study, such as e-learning or virtual learning, or in hybrid models (b-learning) (Balladares-Burgos & Valverde-Berrocoso, 2022). Similarly, they point to the importance of the inspiration this model has offered in teacher training and the development of digital competencies. These authors, therefore, point to this techno-pedagogical model as an epistemological reference, situating it as a relevant theoretical-conceptual framework for the effective development of digital competencies, understanding as effective those that allow for a better quality of teaching and, finally, a better quality of learning.

3. Methodology/approach

3.1. Methodological approach

The methodology used is mixed, with a pre-experimental design. From a qualitative point of view, a case study methodology is applied (Yin, 1994), and from a quantitative point of view, a special questionnaire is designed. It is important not to confuse case analysis with the case study as a methodology applied in education (Merriam, 1988), since this research aims to obtain detailed information on a specific situation experienced by the university population, students and teaching body alike, specifically in the study of quantitative subjects such as mathematics and statistics. In this case, the students' perception of the change to remote teaching through an unchosen virtual environment as a consequence of the confinement caused by Covid-19 is analysed.

Although most of the literature reviewed does accept that the information obtained with the case study is explanatory and descriptive, allowing for the profiling of specific situations, as well as the application of other quantitative or qualitative methods to obtain more information to reaffirm or refute what has been obtained with the case study (Carrión, 2006; Van Wynsberghe & Khan, 2007), other authors believe that the results cannot be extrapolated to the entire population. For this reason, and given that the circumstances are very specific at this time of generalised confinement, this work is completed with the design of a special questionnaire, thus contextualising the exploratory nature of the questionnaire within the quantitative methodology applied.

In the same way, it verifies the effectiveness of the actions carried out by the teacher under the TPACK model, taking into account both the pedagogical part and the learning environment, both remote and hybrid, with an important focus on technology when developing the different contents.

This quantitative analysis of the data is carried out with the application of the Microsoft Excel statistical package, performing a descriptive and inferential analysis. Furthermore, the use of the survey allowed for a sentiment analysis (Zhang, Wang & Liu, 2018) of the participating students by classifying the students' responses based on positive, negative or neutral feelings about the context of the situation.

3.2. Design

An unexpected radical change in the way of learning does not inspire a pleasant emotion, especially if there is no time or means to respond quickly to said change. After a few moments in which the educational community was overwhelmed by the situation, not knowing how long it would last, it is necessary to "get on with it" to a greater or lesser extent. It is clear that it is no longer sufficient to have content knowledge (CK) alone if it is not accompanied by other teaching competencies. At the university level, with restricted content, tight timetables, a lot of students, and commitments to be met (learning outcomes and competencies to be covered, PK), there is barely any time for a global reassessment and redesign, and above all, time to think on how to implement it at a practical level (TPACK).

The main problem to be solved is to find how to quickly adapt the face-to-face model to a different one, while maintaining the essence of the teaching already initiated in the classroom. Most of the students were at that time dependent on this face-to-face model, so the actions carried out were intended to ensure that they continued to feel accompanied in the teaching and learning process (PK). Furthermore, it is assumed that said adaptation must meet the ambitious objective of ensuring that learners not only continue their education and not drop out due to the uncertainty of the situation but that they actively participate as they would in face-to-face (PCK) circumstances. The aim is to establish conclusions that allow us to detect the weaknesses and strengths (PK) that students present when taking quantitative subjects remotely, rejecting from the outset the simple provision of written material, such as notes prepared in PDF, and to find out whether they have sufficient skills and competencies acquired to acquire training in content with a high digital load (TK, TPK), and if not, to find the appropriate tools for this to happen (TCK).

In the case presented here, several elements are chosen together in order to comply with the TPACK model presented above. The importance of maintaining close and constant contact with students with whom the physical contact of the classroom has been lost is valued as one of the fundamental premises for achieving positive results in their learning (PK). It was decided to move away from a totally asynchronous mode, and that they should, at least, continue to hear their teacher's voice, using the same rhythm, with the same inflections while complicated concepts are being explained or exercises are being developed. What is important is to be aware of the need to continue to develop a support system for their learning, paying attention to their different needs (KP). By doing this, the students' interest and motivation are maintained, ensuring that their attention is not lost during the content's presentation (PCK). On the other hand, it is not considered appropriate to equate the two hours of face-to-face classes with two hours of online classes, basically due to the lack of material and technological resources, taking into account the type of subject to be taught, where face-to-face classes fill blackboards and blackboards with formulas and exercises, and considering the change in family and personal circumstances that affected the students at that time.

There is no doubt that the use of video to motivate, engage and allow the student to feel the proximity of the teacher is widespread and well known, and it is evident that the use of didactic video also allows, depending on the desired purpose, to interact with the audience during its development and subsequent use (García-Matamoros, 2014). Hence, one of the main reasons for the consensus on its use (TK) as a didactic tool is because it allows the possibility of pausing, going back, and even viewing its content several times. This makes both learning and following the classes very interesting, as the contents are presented in an attractive, different and understandable way for the proper understanding of mathematical concepts. At the same time, using voice or gestures, the teacher conveys the intensity, importance and emotion that the pupil receives (TCK). Virtual communication is therefore carried out, and is complemented a posteriori by the interactive participation of students in live video classes, virtual forums and interactive chat, eliminating one-way communication. In addition, this format allows for recording so that, through its use, we can indirectly empathise with the students' personal, family and even health circumstances at that moment, facilitating synchronous or asynchronous monitoring of the learning process.

The design and programming of these videos allow a wide range of content (TCK) to be produced and uploaded to the institutional repository created for this purpose, "TV URJC" (https://tv.urjc.es/), which contains the material produced ad hoc for each of the subjects analysed, as well as facilitating access to it through the virtual classroom, a space shared with the students enrolled during the academic year.

In some cases, for adapting, apart from Moodle's own tools, a Chromebook, a stylus and some interesting extensions are used to record live video explanations in different formats (TK). In others, using mobile phone applications and other material resources, in order to provide the same service. Because often it is not a question of using very sophisticated technical means, but of having the enthusiasm to do it as well as possible.

Furthermore, alongside them and as complementary material, all the written material used for the preparation of the videos is made available to the students, so that they have a small repository with all the exercises ordered and solved with the digital whiteboard. All this was accompanied by video classes uploaded on different systems, which became virtual spaces in which to share doubts, concerns and practices, as well as a space in which to assess the academic progress of the students, offering feedback to the group and guidance to encourage participation and formative assessment (PCK, TCK, TPK and finally TPACK). It became a context in which to correct mistakes and provide emotional support for study. Two videoconferencing systems are used for this purpose: *Blackboard Collaborate and Microsoft Teams*. Similarly, the forums are used to share doubts, and working groups are set up to solve problems. It is surprising when, during the adjustment process, there is an express request from some students about the possibility of the teaching staff providing theoretical and practical material from the lectures given prior to the lockdown, as many even see the possibility of taking up again remotely what they had given up when the classes were face-to-face.

Given this situation, and due to the impossibility of attending the classroom in person, the (PK) assessment has to be adjusted. Students are then challenged to develop and solve various subject block tests themselves by participating in specially created virtual workshops (TPK). The task proves to be very successful as it gets them to think about what they have understood, leading them to learn how to pose problems with solutions by controlling the main variables: problem-solving teaches them to solve challenges, overcome difficulties and make decisions. All of this in turn must be shared with their peers virtually, thus taking advantage of collaborative intelligence and entering into a process of formative assessment (Popham, 2013) through peer review (PK). This makes it possible to discover the possible mistakes made by their peers, highlighting a priori that these mistakes are necessary and a preliminary step for good learning, allowing them to get feedback.

3.3. Sample

The actions are carried out with students belonging to the Bachelor's Degrees in Marketing, Double Degree in Business Administration and Management and Law, and Double Degree in Business Administration and Management and Tourism of the Universidad Rey Juan Carlos de Madrid, during the 2019/2020 academic year. Specifically, the subjects involved, which have a clear quantitative component (6 ECTS credits), are Statistics

applied to marketing, which accounts for 48.83% of the sample, Financial Mathematics (30.07%) in the first year and Statistics II (29.76%) in the third year. 64% of the participants are women, while the rest are men. The sample is significant at a 90% confidence level and a margin of error of 5%.

The following table shows the distribution of participating students by degree and subject.

Degree	Subject	Sample
Double Degree in Business Administration and Management, and Law	Statistics II (Statistical Inference)	64
Double Degree in Business Administration and Management, and Tourism	Financial Mathematics	30
Degree in Marketing	Statistics applied to marketing	105
Other degrees (double degree students attending the core group)	Financial Mathematics	16
	Total	**215**

Table 1. Participant sample

This is a simple random sampling, the informants in the research being the students studying these subjects at the time of confinement. The aim is to find out whether they are prepared to receive remote training not chosen for the quantitative subjects of the university degrees, and if so, to see how they adapt to it by getting to know their opinion, as well as to contrast this with the actions carried out by the teaching staff participating in the application of the TPACK model.

3.4. Data collection instruments

Once the new teaching method has been designed, and following a few weeks of implementation, the research is completed with a quantitative tool (TK), designed ad hoc to assess and quantify the degree of acceptance of this paradigm shift in the way of teaching, and also to assess and gather information on the relevance of the tools and the best combination of them to achieve the objectives pursued according to the "face-to-face" profile of the student (PCK).

The selected student informant has the link to the survey available in the virtual classroom, which they can answer voluntarily and anonymously at any time. Their participation is not compensated, so there is no reward for answering the questionnaire. The Microsoft Forms application (part of the Office 365 package) is used, consisting of differentiated blocks with a total of 20 questions. The first seeks to describe the demographic profile of the student body in the pre-Covid-19 situation. The second relates to the aftermath of its arrival and the adjustment to the new confinement scenario. Likert scale rating questions are used with values between 1 and 5, where 1 means *completely disagree with the proposed statement* and 5 means *completely agree*, as well as dichotomous closed questions, and some ordinal and multiple-choice questions. Also included at the end are some open questions for the students to express their opinion, as face-to-face students, on the advantages and disadvantages of remote teaching in an exceptional and obligatory format, in order to carry out the sentiment analysis.

Similarly, the aim is to find out the degree of student satisfaction with the work carried out by the teacher, as well as with the tools that have been used, in such a way that personal feedback can be obtained that serves to define optimal strategies in the teaching and learning process.

The assessment and evaluation of the content of the questionnaire were carried out by seven experts: two statisticians, two mathematicians, two experts in neurodidactics and one in communication. Its design takes into account previous work related to e-learning.

4. Results

The results of the information use are obtained after carrying out a descriptive analysis of the main variables, calculating position and dispersion measures of the responses of 215 informants out of a total of 290 enrolled students. In addition, in order to determine the difference in the behaviour of each individual participant with respect to their attitude in following the subjects taught remotely, before and during the confinement, the parametric Student's t-test is applied as the distribution of the contrast statistic.

With the participation of 74% of the students enrolled in the three groups, the data analysis is structured based on following blocks: Academic situation before and during the Covid-19 lockdown; student adaptation to compulsory e-learning, and application and perception of digital tools.

4.1. Academic status before and during the Covid-19 lockdown

As can be seen in the sample of participants, although most of them live in the Autonomous Community of Madrid during the academic year, the situation forced more than 10% of them to change their place of residence and follow the classes from other places of residence than the one they had at the beginning of the academic year.

In terms of attendance, they are asked to rate from 1 to 5 how well they follow the lessons. Before confinement, the majority of students, particularly in the higher grades, scored an average of 4.30 out of a total of 5 points, with an almost zero drop-out rate (1.1). In the same way, class attendance among students in the first years is very close to 4 (3.90 for statistics and 3.93 for mathematics), showing very low levels of dropout in the three grades analysed before the lockdown caused by Covid-19 (see Table 2).

	1st year Applied Statistics	1st year Mathematics	3rd year Inferential Statistics
Total, attended class every day	3.90	3.93	4.30
Attended class occasionally but got the class notes.	2.43	2.10	1.81
Never attended class but got the class notes.	1.30	1.30	1.36
Dropped out of the subject	1.30	1.13	1.11

Table 2. Attendance in face-to-face classes before confinement

Based on the situation we are all aware of, at the time when the State suspended face-to-face classes, we wanted to find out how the pupils fit in with the transition to e-learning, so we asked about the frequency, timing and follow-up of the subject. More than half, 51%, say they go online every day, with 38% saying they go online in the morning following the live lessons. This result confirms the success of the synchronous planning, taking into account the timetable followed in the face-to-face classes, thus avoiding possible overlapping with other subjects.

In addition, an analysis is made of whether the perception of the follow-up of face-to-face classes in the initial situation varies significantly from the follow-up in the online modality. To this end, the respondent is asked to rate both situations with a score from 1 to 5, with 1 being completely disagree and 5 being completely agree. The difference between them, face-to-face attendance (group 1) and remote attendance (group 2) is 0.63 points, for a range of 0.38 to 0.87 points and a confidence level of 95% when analysing the whole sample. This difference in means is highly statistically significant at $p<0.0001$. The parametric Student's t-test for related samples is applied to compare a group of subjects at two different points in time; in our study, the two points in time analysed are before and during the Covid-19 lockdown. The values used for the calculation are a t-value of 4.9879, a differential of 382 and an error of 0.125.

	Before	After
Group	Group 1	Group 2
Mean	4.05	3.43
SD	1.21	1.23
SEM	0.08	0.09
N	215	215

Table 3. Differences in the assessment of the two time points pre Covid-19

Yet, if we analyse the behaviour of first-year students with respect to class attendance by applying Student's t-test, we can see that the difference in means decreases with respect to the results obtained in the previous analysis, although it is also considered a statistically significant difference, since it is 0.48, for a significance level of 95% at a confidence interval of 0.18 to 0.79 points, and a $p<0.0001$.

First-year students	**Before**	**After**
Mean	3.90	3.42
SD	1.22	1.25
SEM	0.11	0.11
N	135	124

Table 4. Monitoring of classes before and during the Covid-19 lockdown

When analysing the monitoring of face-to-face and remote classes (see Table 4), it is the students in the higher years, specifically in the third year, who show a difference in averages of 0.67 points. Many of those who do not log on daily argue not that they have dropped out but that they have to balance their education with personal situations arising from the lockdown, using a non-asynchronous model of monitoring. Even so, more than half of them log on in the morning. There are several reasons for this decrease in class attendance, including caring for family members, testing positive for symptoms, having to share computer equipment or combining their studies with telework.

These results confirm, a priori, the need to include audiovisual tools (TK) in the content planning (CK) of the subjects, especially if they are of a quantitative nature, which facilitates the student's correct monitoring, even with asynchronous learning but which allows them to make it compatible with other obligations (TCK). It also meets the needs of those who refer to the materials during the assigned hours of these subjects. Video thus becomes the ideal tool to meet this need, and, together with live video classes, allows for a somewhat less distant contact to be maintained.

4.2. Adaptation to e-learning

In order to find out the degree of adaptation or perception of the students' virtual teaching, their opinion is requested, evaluating the proposed statements from 1 to 5 on a Likert scale, with the same meaning as mentioned above. More than half agree or strongly agree that remote teaching serves more to consolidate knowledge than to learn completely new concepts, with an average score of 3.18 out of 5. As expected, almost 30% agree that remote teaching makes immediate feedback somewhat difficult (see Table 5).

	M	**Mo**	**SD**
They serve to consolidate knowledge but not so much to learn new concepts.	3.18	3	1.31
They are as effective as face-to-face classes.	1.87	1	1.11
They encourage virtual relationships	2.35	1	1.15
They keep you up to date with the latest news on the subject at all times.	2.86	3	1.28
Makes it difficult to get immediate feedback	3.57	4	1.26
Encourages self-learning by seeking out other complementary resources	2.86	3	1.15
They allow students to pay continuous attention	2.10	1	1.27

Table 5. Perception of online teaching

These results provide an image of the importance of ensuring that students experience a more positive perception of the content of the classes taught remotely, since the aim is not only to consolidate their knowledge but also to ensure that the planned content is delivered in its entirety.

In order to overcome the perception that there is a comparative disadvantage between face-to-face and online teaching, it was decided to boost student motivation and attention by including challenges in the methodology (PK) that favour self-learning. For example, participation in the development of virtual workshops in which students have to prepare question banks with errors in the elaboration, having the challenge of detecting them and encouraging self-learning through error. The Virtual Classroom becomes a virtual collaborative space (Lázaro, Abia, Calvo & Gómez, 2020) where, in addition to having the material and technical means to advance their learning, they can interact with the teacher and visualise the work done by their classmates.

4.3. Application and perception of digital tools

The second part of the questionnaire provides data corresponding to the answers on which tools they consider essential for monitoring online classes. In it, they give 12 proposed resources a rating from 1 to 5, with 1 being the least important and 5 the most important.

Table 6 shows, in order, from highest to lowest, the descriptive results of the assessment of the tools recommended and of the student's follow-up of the material provided. The five most highly rated were the explanatory videos made by the teacher with an average of 4.7 points out of 5, notes (4.5), tutorials (4.3), videoconferences (4.2) and PPT or Genially presentations (4.1). 96% of those surveyed gave 4 and 5 points to the explanatory video pills made by the teacher as an indispensable resource for following the contents of the subjects. Video thus becomes a tool to engage the learner and the teacher on a regular basis.

Variable	Mean	Standard deviation	Frequency
Explanatory videos made by the teacher	4.76	0.623	96.29%
Additional material provided	4.59	0.879	91.62%
Tutorials	4.31	1.021	84.72%
Videoconferences	4.26	1.077	81.48%
Power point or similar presentations	4.16	1.105	75.46%

Table 6. Assessment of didactic tools used

In order to confirm which resources are indispensable for e-learning classes, both synchronous and asynchronous, they are asked to choose only three out of thirteen resources. The combination with the highest score is made up of the explanatory videos made by the teacher (55%), the videoconference and the additional material necessary to follow the subject, and prepared by the teacher.

Also, in this second part of the questionnaire, they are asked to evaluate the effort made by the teacher during the whole period of lockdown and until the arrival of the regular examination (TPACK). The average mark for the three degree courses was 3.67, with 3.7 out of 5 being the mark obtained for the effort made by the lecturer in these subjects compared to the rest of the degree courses.

From the point of view of academic performance, they are asked about the expected grade, despite the circumstances in which they have found themselves. The responses obtained reflect a clear optimism as 96.7% of the sample expect to pass, and almost half of them expect to achieve at least a 7 out of 10. Being motivated to succeed in the subject is undoubtedly the first step to avoid dropping out and achieving success.

In order to compare expectations with actual performance, expectations are set against out performance rates. By way of example, only the largest group is analysed, the case of Statistics Applied to Marketing (48.83% of the sample), so that students face the same tests and correction criteria, thus avoiding problems of heterogeneity in the comparison. Specifically, a pass rate of 94.79% was achieved for the academic year 2019/2020, which indicates that the deviation is minimal between what the students themselves expect and their total results obtained.

The final block of the questionnaire allows for a textual analysis focused on sentiment analysis. To do this, they are asked to identify in three words what it means to them to take these subjects remotely, on an exceptional basis. Due to the descriptive richness of all the words evoked, the complete list is presented separating them into those with positive, negative or neutral nuances and ordered according to frequency of repetition (from highest to lowest).

The textual analysis allows us to visualise the existence of 68 positive words that identify remote teaching with terms such as attention, better, necessary, adaptable and dedication, among the top five (see Table 7), and other positive words, although less frequent, such as challenge, support, autodidactic, help, novelty, practice and responsibility, which are found in the last position of the list presented. Thus, in this context, a ranking is drawn up, with the twelve listed in Table 7 being the most used, despite the fact that together they represent only 29.95% of the total number requested. Likewise, on the negative side, the twelve most frequently used words are shown in order of frequency of occurrence (from highest to lowest) out of a total of 91 words obtained, accounting for 40% of the total responses: difficult, complicated, impossible, confusion, stress, overwhelming, complex, uncertainty, demotivating, different, better to attend class, insufficient. The classification based on neutral terms is dismissed as non-existent.

	Negative	Positive
1	Difficult	Attention
2	Complicated	Better
3	Impossible	Necessary
4	Confusion	Adaptable
5	Stress	Dedication
6	Overwhelming	Feedback
7	Complex	Constant
8	Uncertainty	Organisation
9	Demotivating	Time
10	Different	Work
11	It's better to attend class	Help
12	Insufficient	Innovative

Table 7. Sentiment analysis on online teaching

As a complement to the above descriptions, some open questions are collected in which they are asked to give their opinion on the advantages and disadvantages they believe exist in taking part in this kind of subject in a virtual format. Thus, despite the circumstances and the fact that there is no other alternative, they acknowledge as an advantage the fact that they can follow the classes asynchronously and combine them with other aspects of their personal lives. The students highlight the possibility of watching the videos repeatedly, logging on without timetables and being able to organise their own study time, and they also consider that this way of learning enhances their self-learning, although they recognise that they prefer to attend class due to the direct contact with their classmates.

5. Conclusions

The recent pandemic has disrupted our personal and professional lives completely. Even at the academic level, everything has changed: the context, the form, the methodology, the activities and evaluation systems, but not the objectives to be achieved. It is not for nothing that the education system must ensure, in any context, that pupils achieve the learning outcomes and acquire the competencies planned in advance.

Those of us who devote ourselves to education have been forced to take a leap into the void, to jump headlong into new ways of reaching our students, all without losing the essence or sacrificing content, and in many cases making it clear that there was no alternative plan to face-to-face education (Aznar Sala, 2020).

An important aspect that could also be the subject of study is whether in this process all teachers have really moved towards developing a true "online education" by developing digital and communicative competencies for it. Any subject to be taught requires a prior planning period, whether it is the responsibility of a single teacher or

the result of the coordination of several teachers, and requires both an appropriate timing and an assessment that is in line with the methodology used, and the contents taught (PCK). The reality is that, under the circumstances, it was difficult to have the material time to work on all of this but an attempt was made, thanks in part to the fact that, from the outset, there was already valuable technological know-how (TK) and the necessary means. All of this was under the responsibility of knowing that we had students ahead of us who were not only being affected by the situation at an academic level but also had high levels of anxiety and stress, produced both by the situation and by being involved in worrying family circumstances.

Lockdown has revealed that the digital competence of both teachers and students is, in many cases, still far from reaching the necessary levels, at least for didactic purposes (Prendes, Gutiérrez Porlán & Martínez Sánchez, 2018; Guillén, Ruiz Palmero, Palacios Rodríguez & Martín Párraga, 2021; Viñoles-Cosentino, Sánchez-Caballé & Esteve-Mon, 2022). The development of all the knowledge that is necessary in an environment of uncertainty would allow teachers to be more critical of their activity, and to grow professionally (Cabero-Almenara et al., 2015). Moreover, when this change occurs, the weaknesses of the system and those of its members are clearly revealed. Therefore, it is not always easy to apply the TPACK model with all its subscales. Nevertheless, at the same time, the great effort made by both parties to adapt, reschedule classes, modify methodologies, and manage a contact that could only take place at a distance and through screens, has been evident. Undoubtedly, many of our students have already grown up with screens but they were not used to learning through them. Clearly, once the model has been established among the researchers involved, and as students and teachers become immersed in an increasingly digital environment, it would be interesting to extend the study to more groups and degrees, as well as to continue researching which aspects of teaching adapted to this emergency situation are here to stay.

This study has aimed to analyse precisely the students' perception of the hasty transition to e-learning, taking into account the importance of the teacher's need to have acquired the different dimensions of the TPACK model. It should be noted that a common handicap associated with teaching at this level is high drop-out rates, especially in quantitatively intensive subjects, particularly in social science degrees. Considering distance learning, these rates soar, as distance learning often generates a sense of remoteness, feelings of frustration and discouragement that can lead students to develop even a certain degree of anxiety towards their studies.

Furthermore, as with the study conducted in Gómez-Gómez (2021), it was found that students, even in a virtual learning environment, found it very positive to collaborate and work in teams. Therefore, in the implementation of the transition, efforts have been made to promote the use of tools that take advantage of this collaborative intelligence (TPK), to train individuals who can act both autonomously and then interact in a digital context, taking advantage of and sharing knowledge, creating a community. What is significant is not the space in which learning takes place but the way in which it takes place; simply by transferring the physical space to a virtual one, together with our desire as teachers to get our students to learn, and to be motivated by it. In short, reaching the full potential of the TPACK model.

The e-learning format, according to several authors such as Bakhronova (2021), is unlikely to replace traditional forms of learning. On the other hand, however, it is important to bear in mind that the new opportunities it has brought with it cannot be ignored. From here on, what is interesting is to have learned both from this new model and from the new interaction with the students, knowing that, if necessary, the knowledge and tools needed to be able to take advantage of the benefits of online learning in an effective way are available. Learning that, in the words of Balladares-Burgos and Valverde-Berrocoso (2022), the digital transformation must now expand towards an education that combines the face-to-face with the virtual, the synchronous with the asynchronous, and the physical with the digital.

Declaration of Conflicting Interests

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