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An Assessment of the Impact of Teachers' Digital Competence on the Quality of Videos Developed for the Flipped Math Classroom

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Abstract: The aim of this research is to determine the impact of perceived Teachers' Digital Competence (TDC) on how well math teachers prepare the educational videos needed to put the flipped classroom model into practice. In preparing the videos, the teachers had to select pre-existing audiovisual material and then edit the content to adapt it to the flipped classroom. Described here is a non-experimental study of a sample of 50 teachers pursuing a Master's degree in Secondary School Math Education in Spain. This is a preliminary univariate descriptive study of the relationship between TDC and the quality of videos prepared. Possible correlations between these two variables and between the characteristics of the sample are also explored. In general, the teachers had an intermediate level of TDC and prepared satisfactory videos. Nevertheless, the videos were deficient in the sections related to their pedagogical and math instructional components. No correlation was observed between TDC and the quality of the videos prepared. These results indicate that the integration of technological, pedagogical, and math instructional components is more important for developing quality instructional videos than the technological component alone. Teacher training should incorporate elements which emphasize the application of technology to the pedagogical process of math instruction.

Keywords: Teachers' Digital Competence; instructional video; flipped classroom; teacher continuing professional development; math; secondary education

1. Introduction

Teachers are constantly challenged by innovations in the teaching models, technology, and educational tools used to develop courses. Constant innovation means that continuing professional development is fundamental for teachers who want to remain current in their careers. There are projects, such as the Tuning Educational Structures in Europe of the European Commission, that have attempted to describe the known teaching competences [1]. These competencies include innovation capacity and the incorporation of emerging trends in education, including the use of technology [2].

The use of technology is a concept that not refers only to types of instruments and duration of use, but also to an understanding of the how a particular technology is used and for what purpose. In addition, the instructional objectives to be achieved via the use of these instruments have to be clearly delineated. The entire process has to be taken into account, not only the final result. The pedagogical model under which the use of technology is framed is crucial to this process of delineation. One such model is a student-centered instructional strategy known as the flipped classroom model (FCM) [3,4]. In this approach, students develop student autonomy [5]. Individual work is completed outside the classroom, where technology plays a primary role. Collaborative work takes place later inside the classroom [6,7].

In a flipped classroom, the teacher is responsible for preparing the material. Therefore, the teacher has to capably select and edit materials in order to successfully adapt them to the FCM. Many online platforms and video editing tools are available.

In order to be useful within a pedagogical model, these platforms and software have to be selected using a clear set of criteria, as do the types of questions and comments that are added to enrich the video content after editing. Therefore, the ability of the teacher to prepare educational videos for FCM becomes a very important research field.

It is precisely at the selection stage that the digital proficiency of the teacher plays a key role. Likewise, continuing professional development in the use of innovative pedagogical models is crucial. This is because teachers need to be able transfer subject matter using the most effective means available to promote student learning.

The aim of the present study is to assess the relationship between digital proficiency among math teachers and the ability of math teachers to select and edit instructional videos for use within the FCM.

The use of digital resources is highlighted by The European Framework for the Digital Competence of Educators (DigCompEdu) [2] as an essential teaching skill. The DigCompEdu places a strong emphasis on developing the ability to select, share, and generate digital material. This emphasis has led to the development of new evaluation instruments [8,9] to determine how well teachers have adapted to changes that have been made in adopting this general framework [10].

Better training of teachers has reduced the digital divide that separates them from their students. However, teachers' weakest capabilities remain those required to prepare digital content [11].

This work focuses on the ability of a teacher to adapt videos to the needs of the student. In order to understand this research, it is important to consider four points. First, a teacher faces many challenges in adopting the FCM. This is because the FCM requires many changes with respect to traditional formats, such as the role of the teacher and student, changes in scheduling, etc. Second, there have been many advancements in audiovisual tools and a proliferation of new video platforms. Third, considering the amount of time, money, and knowledge necessary to create an instructional video, the ability to select an appropriate video (instead of creating a new video de novo) can save a teacher a lot of time. Finally, the FCM itself has evolved over time. Sams and Bergmann once suggested that teachers should prepare their own videos. However, in light of how far software has advanced and the amount technical knowledge still needed to prepare a video, Bergmann now proposes that teachers instead select existing videos and adapt them to the needs of their audience and active-learning activities. One of the challenges in adopting FCM lies in overcoming the perceptions that teachers and students will be overworked and that good audiovisual material that include activities and also maintain student interest is not easy to come by.

1.1. Professional Teaching Competence and Digital Teaching Proficiency

Student-centered learning forms the backbone of this new educational model. Under this model, students must develop their own work plans and manage their own time. The role of the teacher is akin to a guide. This process has to be accompanied by an improvement in professional teaching competencies, particularly those defined as "generic" by the Tuning Educational Structures in Europe [12]. "Generic" competencies include information management, criticism and self-criticism, and the capacity for applying knowledge to practice [1]. Some of these competencies are analyzed in this study.

When applying a model that relies on the specific use of various Information and Communications Technology (ICT) resources, another critical competency is the ability of the teacher to master and apply these resources during the teaching-learning process. Due to its transversal nature, the European Commission has defined this as a key competency because it impacts the development of other essential skills in all citizens [2].

Some of the elements of Teachers' Digital Competence (TDC) include editing and creating digital content. This includes "repackaging previous knowledge and content, engaging in artistic production,

creating multimedia content, computer programming, and managing intellectual property rights and licenses to use" [9,10].

How well a teacher acquires and develops TDC will directly impact the capacity of their students to develop their own digital competence. For this reason, many initiatives have been established to train teachers in digital competence [13]. The aim is to provide teachers with the tools to apply this competency along the disciplinary, pedagogical and technological [14] axes. This triple axis is the center of the framework known as TPACK (technology, pedagogy, and content knowledge). In this model an effective teaching will be developed if the teacher is able to make use of different knowledge in an integrated way, including knowledge of how the student thinks and learns (pedagogical knowledge), knowledge of the teaching subject (content knowledge), and knowledge of technology. The teacher must be able to interweave these different disciplines avoiding them being unconnected knowledge. Each teaching context must be analyzed and solved using a unique combination of three factors: content, pedagogical and technological.

1.2. Flipped Classroom Model (FCM)

The FCM was concieved out of the need to modify how to work with students in the classroom [15]. A teacher-centered teaching process, in which students simply receive and then regurgitate information, is incompatible with meeting the needs of society. Facing the challenges of the 21st century requires the sort of skills development that promotes problem-solving [16,17]. In shifting from teacher-centered models to a student-centered model [16,18], flipped classrooms move activities that normally take place outside the classroom, such as reviewing lessons and clarifying concepts [17], into the classroom where face-to-face interactions take place. Conversely, the traditional class lecture is assigned for homework along with supporting material that is prepared by the teacher [7].

The flipped-classroom is a relatively new model that emerged in the late 20th century in the US and Canada. However, since its inception, the application of this teaching model has spread exponentially. The FCM has not only become universilized but is also being applied at all educational levels, from the university level [19–24] to secondary and elementary schools [25–28]. Math is one of the subjects most commonly taught within this model [29]. One reason that the flipped classroom model has been so often applied in the math domain is that the hands-on way of clarifying students' doubts is highly compatible with math instruction [28].

An additional advantage is the high accessibility of video tutorials found on platforms such as Khan academy, Mates2, Ticking, and others.

Methodologies such as collaborative work, problem solving, peer-tutoring, etc. are employed in the classroom. Higher order cognitive processes are promoted using these methodologies [4,5,30]. The student becomes aware of his/her own responsibility in the learning process. Meanwhile, the teacher becomes a guide who not only supervises classroom work, but also designs, directs, and reviews the learning that takes place outside the classroom [17]. Indeed, the capacity of the teacher to curate the relevant resources should be intimately tied to the capacity of the teacher to apply the FCM. One of the most widely used resource that has the required properties is the instructional video [31]. This medium allows the teacher to create short lectures that incorporate questions and comments, which, in turn, encourage the student to reflect on the material [32]. Including questions and comments also promotes the transfer of individualized information back to the teacher.

Combining images and explanations via video allows students to develop a better understanding of the material. According to the cognitive theory of multimedia learning (CTML) [33], students learn more when a narrative is employed to tie information together than if a textbook alone is relied upon. CTML explains that "Learning is an active process of filtering, selecting, organizing, and integrating information based upon prior knowledge". Likewise, the individualized attention that accomponies the instructional videos helps those with learning disabilities to achieve more [34].

Increasing student performance, encouraging student interest, and developing critical thinking skills are clear and strong incentives for adopting the FCM. However, student and teacher feedback

alike suggest that there is room for improvement in both the quality of videos that teachers have been producing and in the amount of time invested in editing and viewing [6].

The FCM has opened up new avenues for the teaching and learning of math. For example, Talbert [29] demonstrated that the flipped classroom is particularly well-suited for teaching linear alegebra. This is because linear algebra instruction combines the ability to carry out relatively simple calculations with the ability to enage in deeper concept development.

In a review of more that 1000 articles on the application of the flipped classroom to math instruction, Lo et al. [35] articulated 10 principles for contructing a flipped classroom. The three that refer to the components outside the classroom are: "Principle 3: Consider presenting introductory materials and providing online support via video lectures; Principle 4: Enable effective multimedia learning by using short instructor-created videos; Principle 5: Use online exercises with grades to motivate student class preparation". In order for teachers to be able to design, select, and edit videos that meet the requirements, it is essential for them to be aware of the guidelines.

The aim of this work is to therefore assess the ability of teachers to adhere to principles 3, 4, and 5, which are fundamental to the correct design of the flipped-classroom model.

1.3. Video as a Resource for Flipped Classrooms

Videos are an important instructional tool for teaching math both in the face-to-face environments found in flipped-classrooms and in e-learning platforms or Massive Open Online Course (MOOCS). Walsh et al. [36] stress the importance of this type of resource acquire a leading role in the development of skills and not as a simple resource for reviewing the contents. A refinement of these videos allows the student to improve their learning experience [37].

In using video as an out-of-class instructional resource, the teacher participates by making selections and editing, etc. [38]. The content of the videos should accord with the level of education of the students [39] and the videos should be prepared using the principles of the flipped classroom as guidelines [4]. Students should watch the video before coming to class. The videos should prompt the student to reflect on whether or not they understood the contents. Questions left unanswered should, in turn, be addressed in the classroom [40].

Using videos from Khan Academy, Technology, Entertainment and Design (TED), and YouTube Channels [23] does not by itself mean that flipped learning is taking place. Videos might simply mimic the traditional lecture format. For example, a video may simply show a teacher explaining how to solve an algebra problem [41]. Preparing materials for a flipped-classroom requires a significant investment in time and resources [42]. In fact, it takes 6 times longer to prepare material in a flipped classroom than in a traditional one [43]. Teachers have to master course content, to be sure. However, they also need to focus on digital skills development and on strategies for selecting appropriate technologies. Teachers also have to learn to integrate the tools that facilitate teacher-student interactions and communication in order to improve feedback and in order to faciliate the development of objectives for learning that takes place outside the class [6].

In selecting a video that fulfills the requirements of a flipped classroom, the teacher must evalute the following aspects: curricular, technical (duration of video), expressive (type of representation) aesthetic, mathematical, pedagogical, and intructional (content difficulty) [44]. The teacher also has to consider possible problem solving scenarios, the existence of different record representations, the clarity and precision of the definitions and how the premises and procedures are structured.

An example of attending to curricular aspects is that, when analyzing the suitability of the videos of channels like YouTube™ for teaching proportional distribution problems, great disparities in content representativeness are observed [45]. Content difficulty should be accounted for. Not everyone works with a video in the same way. Sometimes the content must be reinforced in class [46]. In these cases, the teacher should prepare materials that allow him/her to gather information about student learning. This also means incorporating tools that provide complementary feedback, such as on the twitter social media platform [35]. The mode of representation of the mathematical symbols used in the video

must also be taken into account. Representations may vary according to the source. It is particularly important for the students to understand and become familiar with the teacher's own notations with those from other sources [47,48].

The duration of the video is a factor to take into account when considering technical and expressive aspects. As a general rule, videos that are longer than six minutes in duration should be divided into smaller segments in order to reduce the dropout rate [49]. The dropout rate is defined as the percentage of watchers who stop watching before the video ends. Videos should incorporate dynamic presentations. A sequence of slides is not as effective as recording a blackboard being written on [50]. In the latter case, the problem solving is developed in a step-by-step process.

Interactive material such as quizzes or discussion forums [41] should be incorporated into the video lectures [51]. This material both allows the student to check their progress and serves as a tool to help students reflect on their degree of understanding. Simultanouesly, this material allows the teacher to monitor student progress and provides information that can be used to rearrange and modify future classwork [35].

Climent et al. [16] assessed how effective video was in training math teachers. In this study, math teaching and learning conceptionsas well as teacher knowledgability were analyzed while teachers watched a video case in primary education. The authors concluded that replacing academic approaches to math instruction with active methodologies and new technologies such as videos is beneficial.

In establishing a flipped math classroom model, Schneider and Blikstein [17] combine video with a tool known as a "tangible user interface" (TUI). The module they developed covered the subject of probability. TUI users interact with digital information via a physical environment. The authors of this study assessed the interaction between videos containing theoretical information and experimental sessions.

2. Methodology

2.1. Objectives and Hypothesis

The aim of this research is to determine how important TDC is among math teachers in capably selecting and editing audiovisual material when preparing instructional videos with Edpuzzle (USA) designed to put the FCM into practice.

With this aim in mind, the following research questions were posed:

- How do math teachers self-perceive their TDC?
- Are math teachers able to prepare quality educational videos for the flipped classroom?
- How well do math teachers' perception of their TDC correlate with the skill with which they prepare educational videos?

The working hypothesis of this study is that math teacher TDC levels are directly related to how well teachers select and edit educational math videos for use in the flipped classroom

2.2. Sample

This study included a sample of 50 teachers pursuing a Master's degree in Math Education at an online Spanish university in the 2018–2019 academic year. This non-professional degree was part of these teachers' continuing professional development.

Using a survey, the characteristics of the sample were determined according to age, years of teaching experience, use of the FCM, use of educational videos, and how often teachers record, select or edit instructional videos.

52% of those surveyed were between 30 and 40 years of age. A total of 32% were over 40 years of age and only 16% were between 20 and 29 years of age. The majority (60%) had more than six years of teaching experience, while 30% had between one and five years of experience and 10% had less than one year of experience. A total of 42% of the respondents indicated that they never used the FCM in

their teaching. Meanwhile, 50% rarely employed the model, and only 8% often employed the model. In addition, 38% frequently used educational videos, 58% rarely used them, and 4% had never used an educational video. A total of 50% of the respondents had never made their own educational videos, 46% rarely made videos, and only 4% frequently did so.

2.3. Research Design

This was a non-experimental study that consisted of two parts. On the one hand, a preliminary descriptive univariate study was carried out on self-assessments of TDC and video production. On the other hand, a correlational study was carried out to determine whether or not there was a relationship between the variables "grade awarded in the video-based activity" and "digital proficiency of each teacher" as well as whether or not there a was a relationship between these variables and the characteristics of the sample.

2.4. Information Collection Tools

Perceived-TDC was carried out using the validated questionnaire assembled by Touron et al. [9]. This questionnaire is based on the INTEF Common Framework for the Teachers' Digital Competence [10]. This instrument consists of 54 items distributed in five dimensions: information and information literacy (D1), communication and collaboration (D2), digital content creation (D3), security (D4), and problem solving (D5). The degree of knowledge was rated using a Likert scale from 1 to 7. In this way, proficiency levels were established (A0, A1, A2, B1, B2, C1, C2), where A0 corresponded to those who were completely unskilled with respect to TDC and C2 corresponded to a complete mastery of this competency. Overall perceived-TDC was rated by percentage and levels were determined using the following scale A0: [0, 14.3), A1: [14.3, 28.6), A2: [28.6, 42.9), B1: [42.9, 57.2), B2: [57.2, 71.5), C1: [71.5, 85.8), C2: [85.8, 100].

Instrument Validation

The instructional video evaluation instrument was based on previously reported studies [44,52,53]. The first draft consisted of 26 items distributed in 4 dimensions: V-D1: Curricular aspects (5 items), V-D2: Technical, aesthetic, and expressive elements (6 items), V-D3: Pedagogical aspects (6 items), and V-D4: Math education aspects (9 items).

A panel of experts in the field serving as raters was used to validate the evaluation instrument [54]. First, the experts were selected according to the aim of the study, as were the dimensions and indicators used to measure each item in the evaluation. Second, each expert was contacted and informed of the purpose of the test. Finally, the relative weight of each dimension was fixed and the inter-rater variability was calculated.

Ten members of the panel were experts in the field of math education and/or educational technology, and in secondary education. The panelists were asked to rate the clarity, coherence, and relevance/pertinence of each of the items and dimensions. The panelists scored these as either "adequate" or "inadequate". The raters were asked to provide comments in the case a dimension or item was considered "inadequate".

Cohen's Kappa Coefficient was used as a measure of the inter-rater variability. Confidence intervals were determined for kappa at a confidence level of 95%. See Tables 1–3 for the results for clarity, coherence, and pertinence in each dimension.

Table 1. Cohen's Kappa values for inter-rater variability on the scale of Clarity.

Coefficients	Clarity				
	Total	**V-D1**	**V-D2**	**V-D3**	**V-D4**
Kappa	0.6171	0.52	0.5111	0.733	0.6642
Fleiss SE	0.0292	0.0667	0.0609	0.609	0.0497

Table 2. Cohen's Kappa values for inter-rater variability on the scale of Coherence.

Coefficients	Coherence				
	Total	**V-D1**	**V-D2**	**V-D3**	**V-D4**
Kappa	0.7880	0.52	0.7481	0.8	0.7333
Fleiss SE	0.0292	0.0667	0.609	0.609	0.0497

Table 3. Cohen's Kappa values for inter-rater variability on the scale of Pertinence.

Coefficients	Pertinence				
	Total	**V-D1**	**V-D2**	**V-D3**	**V-D4**
Kappa	0.8188	0.68	0.9333	0.8148	0.8222
Fleiss SE	0.0292	0.0667	0.0609	0.609	0.0497

The values of Kappa for Coherence and Relevance of items and dimensions were excellent (>0.75), indicating a high level of agreement between the raters [55,56]. However, Kappa values for Clarity fell within a range of "intermediate to good" (0.40–0.75).

Using the data from the rating process as guide, we modified the wording of certain items and switched some items from one category to another, for example, from "math instructional aspects" to "pedagogical aspects". The final version of the evaluation form can be found in Appendix A.

In addition to the content validation, the inter-observer reliability was assessed. The final evaluation form was provided to three potential users who were asked to evaluate two randomly chosen videos from a sample. Intra-class correlations were determined using a two-factor model because the user scores were made on a numerical and quantitative scale of 0 to 1. The intra-class correlation values (for unique mean) were 0.896 and 0.672 for videos 1 and 2, respectively, which confirmed the inter-observer reliability of the evaluation tool.

These statistical analyses were carried out with the SPSS v25.0 software package and the Stats Fleiss Kappa application (written by David Nichols).

2.5. Procedure

One course requirement of the Master's in Math Education curriculum is Programming, Methodology, and Evaluation. During this course, teachers participate in an assessment activity in which they selected audiovisual material found online and then use the Edpuzzle platform to edit the material to prepare videos for use in a flipped classroom setting. teachers receive training both about developing the education model and in the use of the video editing software (Edpuzzle). Teachers can choose to work with audiovisual material already published on a math platform and or to record their own material. These videos, together with the development of two questionnaires, the one for the characterization of the sample and the one for digital teaching competence, are the object of study in this work.

2.6. Data Analyses

A descriptive analysis was carried out to determine the perception of math teachers of their own TDC. Overall TDC and individual TDC dimensions were represented using box blots. The Spearman Rho non-parametric test was used to determine the strength of correlation between the grades the teachers received for the videos and the average TDC score resulting from each teacher's self-assessment. The Spearman Rho test was appropriate here because TDC was assessed using an ordinal scale. The purpose of this analysis was to determine whether perception of TDC corresponded to level of skill in producing instructional videos. The strength of correlation between the TDC and video grade variables and the sample characteristics was also assessed. These statistical analyses were carried out with the SPSS v25.0 software package.

3. Results

3.1. Perceived TDC

The Teaching Digital Competence (TDC) is structured in 5 interrelated competences, being considered D1, D2, and D3 specific for certain uses and, D4 and D5, applicable to any type of activity [10]. D1 and D3 and more specifically sub-dimensions 1.1 (navigation, search, and filtering of information, data, and digital content), 3.1 (digital content development), and 3.2 (integrating and reworking digital content) are areas of interest in this research. This is because the above dimensions are related to searching, selecting, and editing videos.

The perceptions revealed that teachers' median perceived-TDC fell within the intermediate level B1. According to Figure 1, the median perceived-TDC was more than 57%, though the perceived-TDC results ranged from 20% to 90% (with a slight skewing towards higher percentages). In light of the high variance in perceived-TDC ratings, it made sense to assess the frequency distributions according to proficiency level. Twelve teachers perceived to having a level A TDC, 26 to having a level B TDC, and 12 having a level C TDC. Of the teachers at level A, only 5 had a perceived-TDC at level A1. A1 level teachers had a basic TDC and required support in order to improve their digital competence. Meanwhile, 7 of the level A teachers were at level A2. A2 level teachers can exercise a certain level of autonomy and with appropriate support, are able to develop their digital competence.

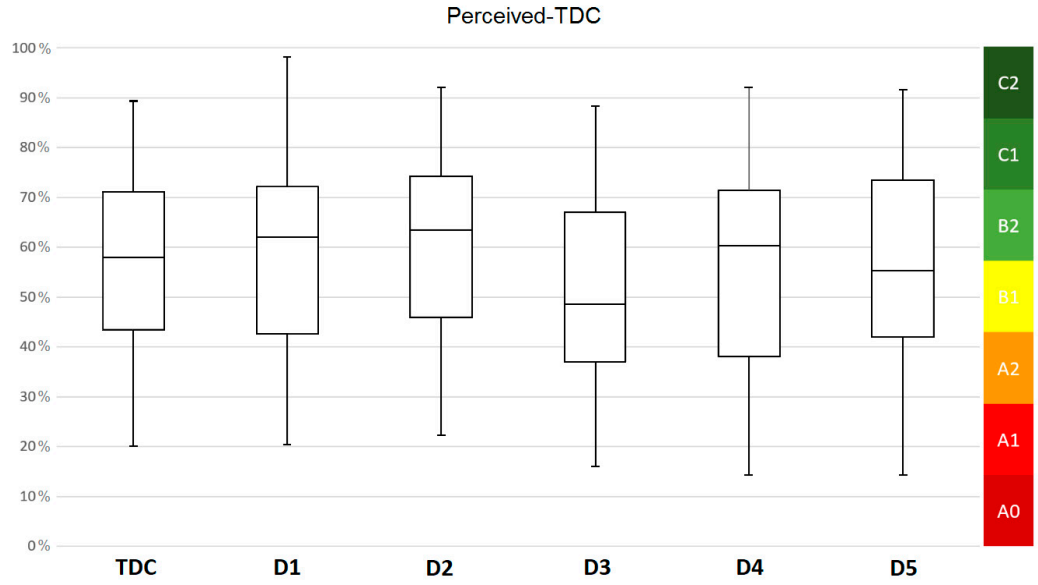

Figure 1. Box diagram showing the frequency distribution, expressed in percentages, of teacher perceived Teaching Digital Competence (TDC) scores and scores in the 5 dimensions of TDC: D1, D2, D3, D4, and D5. The horizontal line within each box marks the median. The lower and upper limits of each box correspond to the 25th and 75th percentiles, respectively. The upper and lower ends of the vertical lines refer to the outliers.

Meanwhile, teachers showed a somewhat higher median level of competence in dimensions D1 and D2 (62% and 63.5%, respectively), reaching an intermediate perceived-TDC level of B2. Therefore, in dimension D1, only one teacher reached a competence level A1, while 14 were at level A2. The competence level for sub-competency 1.1 was higher than the competence level observed for D1 (65% vs. 60%). In the case of D1, only one teacher was found to reach level A1, while 8 were found to be at level A2. The results with dimension D3 were notable because the median score lay below 48% and the high scores in this dimension were lower than the high scores in all other dimensions. A detailed analysis showed that 9 teachers were at level A1 and 11 were at were level A2. When considering sub-competencies 3.1 and 3.2, the average competence ratings were 54% and 48.9%, respectively,

with 8 teachers in both level A1 and A2 for sub-dimension 3.1 and 10 teachers in both level A1 and A2 for sub-dimension 3.2. In addition, within sub-dimension 3.2 there were 2 teachers at level A0. The competence ratings in dimensions D4 and D5 (55%) were very similar to overall perceived-TDC ratings. Regarding the dispersion of the ratings, all the dimensions had a similar variance, although the variance was somewhat higher in dimensions D1 and D4.

When assessing the strength of the correlation between sample characteristics and perceived-TDC (Table 4), a significant but weak direct linear correlation was observed between the frequency of use of flipped classrooms (FC) and the overall perceived-TDC ratings as well as ratings of the various dimensions of TDC. There was also a significant but weak direct linear correlation between the D3 dimension of the TDC (digital content creation) and how frequently videos were used by the teachers in the classroom.

Table 4. Rho Spearman coefficients were calculated for correlations between the sample characteristics and TDC as well as between the sample characteristics and dimensions D1, D2, D3, D4, and D5 and sub-dimensions D1.1, D3.1, and D3.2.

Sample characteristics	TDC	D1	D1.1	D2	D3	D3.1	D3.2	D4	D5
Age	−0.182	−0.232	−0.142	−0.173	−0.215	−0.268	−0.166	−0.123	−0.122
Experience	−0.076	−0.1	−0.009	0.017	−0.12	−0.166	−0.064	−0.091	−0.055
Frequency of FC use	0.405 **	0.358 *	0.218	0.405 **	0.391 **	0.324 *	0.430 **	0.395 **	0.404 **
Frequency of video use	0.249	0.224	0.21	0.26	0.297 *	0.289 *	0.315 *	0.189	0.242
Frequency of video creation	0.188	0.195	0.177	0.196	0.238	0.236	0.263	0.125	0.146

** p-value < 0.001 * p-value < 0.05.

3.2. Evaluating the Intructional Math Videos

In order to answer the research question of whether or not math teachers are capable to prepare quality teaching videos that could be used to apply the FCM, the videos that the teachers prepared were evaluated by the authors according to the abovementioned rubric. This rubric was subdivided into 4 dimensions: V-D1, curricular aspects; V-D2, technical, aesthetic, and expressive elements; V-D3, pedagogical aspects, and V-D4, math instructional aspects.

Videos were scored on a scale of 0–10 (see Figure 2). The median score for the videos was 7.29 points (σ = 1.44), with a minimum and maximum of 4.08 and 9.88 points, respectively. Only five teachers made high quality videos (≥9 points). However, when considering each dimension separately, important differences can be observed. The V-D1 dimension had the highest median score of 9.25 and a 3rd quartile value of 10 points. The averages of the other dimensions successively decreased as the interquartile range increased (Figure 2). A median score of 5.84 points was observed for V-D4, which had highly dispersed scores (s = 2.05). Finally, the distribution of the scores for the V-D3 dimension was the one that most closely resembled the distribution of the scores for the videos.

Individual items were scored on a scale of 0 to 1. The V-D3 and V-D4 dimensions had the lowest average scores and the greatest dispersion in values. However, the following items from VD-3 and VD-4 achieved high average scores (>0.9 points): item 14 (the information presented is mathematically rigorous) and item 16 (the vocabulary and linguistic expressions used are rigorous, comprehensible, and adapted to the students). In contrast, the following items achieved unsatisfactory average scores (<0.4 points): item 18 (the questions added using Edpuzzle encouraged student reflection), item 24 (math content is linked to real-life scenarios or other subjects), and item 25 (links the math content with the historical role math has played in human development). The average scores and standard deviations for each of the items from VD-3 and VD-4 are laid out in Table 5.

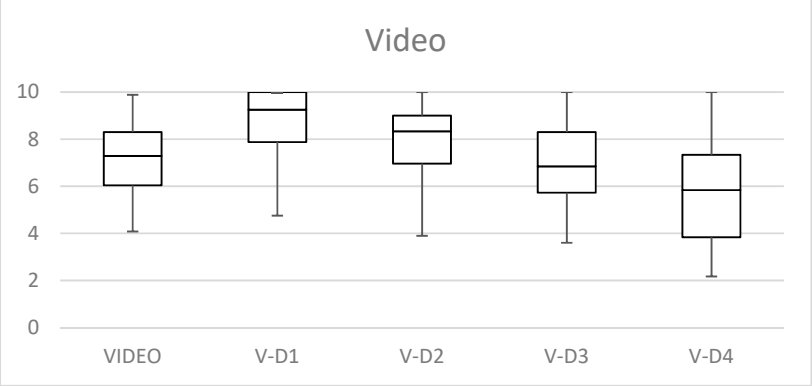

Figure 2. Box diagram showing the distribution of scores for the videos and scores for each of the 4 dimensions used to evaluate the videos (V-D1, V-D2, V-D3, and V-D4). The horizontal line within each box represents the median. The lower and upper limits of each box correspond to the 25th and 75th percentiles, and the lower and upper ends of the vertical lines refer to the outliers.

Table 5. Average scores and standard deviations for items I-11 to I-26 from dimensions V-D3 and V-D4. The average scores that fall above 0.9 or below 0.4 are shown in bold font.

Descriptive Statistics	**I-11**	**I-12**	**I-13**	**I-14**	**I-15**	**I-16**	**I-17**	**I-18**
$\bar{x}$	0.61	0.68	0.82	**0.97**	0.89	**0.93**	0.75	**0.25**
s	0.51	0.35	0.25	0.12	0.20	0.15	0.40	0.33
Descriptive Statistics	**I-19**	**I-20**	**I-21**	**I-22**	**I-23**	**I-24**	**I-25**	**I-26**
$\bar{x}$	0.57	0.49	0.88	0.75	0.74	**0.32**	**0.15**	0.50
	0.35	0.38	0.22	0.37	0.36	0.43	0.34	0.33

Meanwhile, a significant but weak direct linear correlation between the variable "years of teaching experience" and scores in the V-D2 dimension (Rho = 0.288, *p*-value = 0.043) was observed. No other significant correlation between the sample characteristics and the video scores was observed.

3.3. Relationship between Self-Assessments of Digital Competence and Actual Skills Shown When Preparing Math Instructional Videos

To analyze whether there was a relationship between the teachers' self-assessments of digital competence and their ability to select and edit math instructional videos, the videos were first categorized according to the teachers' level of the digital competence (A, B, and C). The teachers' scores in the video preparation training activity were then plotted against their perceived-TDC level (Figure 3). Teacher scores were also differentiated according to their TDC levels: squares for level C (grade > 72%), circles for level B (grade 43–72%), and triangles for level A (grade < 43%). Most of the videos were edited by participants who had a basic TDC level of C (score of 6–8 points). The average video score in this group was 7.14 points, which fell below the overall average. Teachers with an intermediate TDC level (B) received an average video score of 7.38 points, which was above the overall average. Meanwhile, teachers with a level A TDC received a wide range of video scores. Three of these teachers even received unsatisfactory scores. A more detailed analysis of these three videos revealed that in all three cases, the videos were recorded by the teachers themselves, rather than being selected from an online platform and edited. Ultimately, no correlations were detected between the study variables neither overall nor when sorting the sample according to TDC levels.

The results of Spearman Rho test confirmed the absence of any correlations (Appendix B). This correlation analysis was performed using the overall video scores and perceived-TDC levels as well as the dimensions of the video evaluation and the sub-dimensions of the perceived-TDC. No statistically significant correlation (*p*-value < 0.05) was observed between the variable "video score" and the

variable "perceived-TDC". There were also no statistically significant correlations detected between the dimensions of the video evaluation and the dimensions and sub-dimensions of the perceived-TDC.

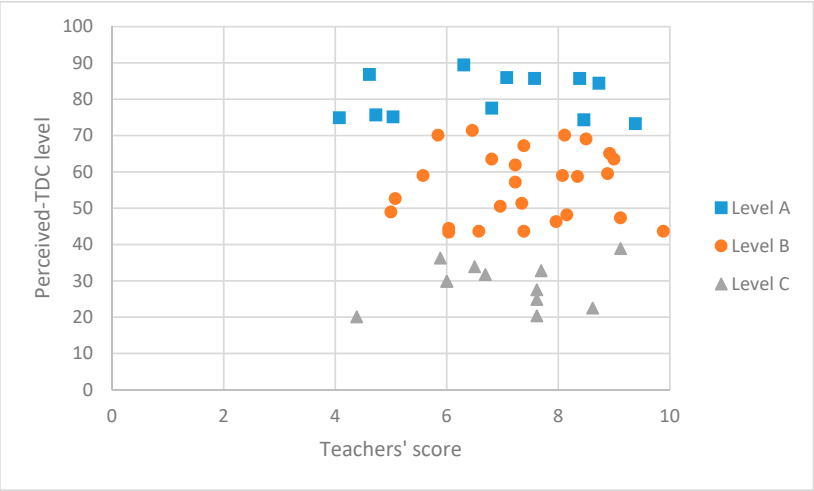

Figure 3. The teachers' scores in the video preparation training course were plotted against their perceived-TDC level. Grades were sorted according to TDC: squares for Level C (>72%), circles for Level B (43–72%), and triangle for Level A (<43%).

4. Discussion

Most of the teachers who participated in this study perceived themselves as having an intermediate TDC level. Therefore, in general, they were able to independently apply their digital competency to solve simple problems [10]. Nevertheless, there was considerable diversity among the subjects in the sample. For example, a large number of subjects considered their level of TDC to be rudimentary. Another group within the sample considered themselves advanced. Past reports have described similar evaluation outcomes [11,57].

When considering the dimensions of the perceived-TDC alone, most teachers were in an intermediate level in terms of information searches. In terms of this dimension, teachers were in a higher level than they found themselves in terms of overall TDC. Therefore, the teachers being assessed had no problem searching for and selecting digital content such as videos. However, in terms of preparing digital content, such as videos, more teachers found themselves in the basic level A1. This number increased when the editing process was included. Therefore, the sample studied here included teachers who did not need help searching for and selecting videos but may have needed help with development and editing [6].

A correlation analysis between teachers' characteristics and their digital competence demonstrated that a higher level of perceived-TDC was linked with a more frequent application of the FCM. This result indicates that teachers with a higher level of digital competence may feel more comfortable adopting a novel methodology that has a strong technology component, such as the FCM. This analysis is consistent with past findings [58]. The association between the dimension of Digital Content Creation and the frequency of video use is also consistent with this model.

Once the perceived digital competence of the study participants was determined, the study shifted to address the question of whether or not these math teachers were able to prepare quality instructional videos in order to incorporate the FCM into their teaching. Most of the videos that were assessed were of good quality. However, many were deficient in some respects and very few were outstanding. In analyzing video scores by dimension, we found that the math teachers had a strong command of curricular aspects. The technical, aesthetic, and expressive elements were properly developed and teachers were able to select videos that were of satisfactory technical quality. It is important to highlight that most of the teachers who created their own videos instead of selecting

a pre-existing video from a math platform had a final product whose technical qualities were not satisfactory. Significant deficiencies were observed when evaluating the videos, with respect to the pedagogical (D3) and math instruction (D4) aspects. In order to explain this observation, we turn to the Technological Pedagogical Content Knowledge or TPACK model [14,59]. This model postulates that for a teacher to be able to incorporate ICT into the classroom, it is not enough to understand technological, pedagogical, and content components in isolation. Instead, a teacher needs to understand how these different components interact with one another, for example via pedagogical Content Knowledge (PCK), knowledge of the use of technologies (TCK), technological pedagogical knowledge (TPK), and technological, pedagogical, and content knowledge (TPACK).

Dimensions D3 and D4 correspond with the TPACK model. In this model, the technological domain, the pedagogical domain, and the content domain are more crucially interrelated. In the dimension of pedagogical aspects (D3), the teachers mainly integrated the technological and pedagogical domains. Therefore, according to the TPACK model, this would imply a low-to-medium level of technological and pedagogical knowledge (TPK). In the math instruction dimension (D4), the teachers integrated the three components of the TPACK model. Therefore, the teachers had at least a minimal level of technological, pedagogical and content knowledge (TPACK). While teachers showed a very good level of curricular knowledge and a great understanding of specific technical knowledge, the scenario changed when addressing the relationship between technology, teaching, and content [60].

An independent analysis of the items in the video evaluations demonstrated that the principle challenges with TPK and TPACK appeared when the teachers used videos to encourage reflection, attempted to link math with daily life or other subjects, or tried to emphasize the history of math and its role in society [61,62].

Finally, the results of this research provides an answer to the question of whether the teachers' perceptions about their own digital competence corresponds in reality to how skilled they are in preparing math instructional videos. Ultimately, there is no evidence for this hypothesis because no correlation was observed between perceived-TDC values and being able to prepare math instructional videos for the flipped classroom. The results indicate that de level of teacher's digital competence was enough to select and edit videos of good quality, but the fact of having a higher level of perceived TDC does not involve an improvement in the quality of the videos. Taken together with that fact that lower scores were assigned in the dimensions of the evaluation that interrelate technology, pedagogy, and content, it appears that digital competence by itself is not a critical obstacle that teachers need to overcome, as others have suggested [63]. The main challenge seems to lie in how to integrate TCK, TPK, and TPACK. Teachers may find it difficult figure out how to successfully present math concepts through technology. Teachers might also have trouble understanding how technologies can change the mode of instruction and how best to set the stage for teaching. In particular, it is difficult to know how to coordinate concrete math activities using ICT to develop representations of concrete concepts in a way that facilitates student learning. Employing ICT also requires knowing how to use technology to motivate, encourage reflection, and link mathematics to everyday life.

In conclusion, the results of our study suggest that math teacher continuing professional development should emphasize an enhanced understanding of how technology can be applied to the concrete pedagogical process of math instruction. This assertion has been made by other groups [63,64]. In order to improve how the FCM is applied to teaching math, teachers need to learn how and why instructional videos improve student learning. Teachers must also grasp the properties of videos that add value to the representation of math concepts, which, in turn, enhances the teaching-learning process in a flipped classroom. In addition, following up on the teacher training would be beneficial as it would help ensure that the training received is adequately implemented [63,65,66].

It is important to underline that teachers who adopt the FCM not only have to be able to search for and select appropriate videos, but also be able to enrich them with questions and reflections. In this way, the final product will have the appropriate level and will fit the specific context of the teaching-learning process.

In light of our findings we propose, on the one hand, to work in the classroom from the perspective of metacognition so that teachers are able to critically self-evaluate how well they select and edit videos for the flipped classroom. On the other hand, our aim is to further clarify the issues tackled in this work. A deeper analysis of the teachers' competencies necessary to work within the FCM in the context of the TPACK model and its multiple relationships will be needed in the future.

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Appendix A

Table A1. Dimensions and items used in the video evaluations.

Dimensions	Items
V-D1. Curricular aspects	The video is appropriate for the chosen course.
	The video is appropriate for presenting the chosen content.
	The video addresses the objectives of the learning experience.
	The video explicitly explains the content contained within it.
V-D2. Technical, asthetic, and expressive elements	The image quality is acceptable (resolution, focus, and brightness).
	The sound quality is acceptable (clarity, volume).
	The texts, graphics, animations and special effects support the instructional objectives.
	The audio-to-video synchronization is acceptable.
	The narrative has an introduction, a body, and a conclusion.
	The duration of the video is acceptable (3–5 min).
V-D3. Pedagogical aspects	The audiovisual document motivates learning (the document is modern, contains attractive graphics, motivational audio, etc.).
	The video is compatible with the instructional methodology being incorporated.
	The presentation is clear and the key concepts and ideas are well-developed.
	The information presented is mathematically rigorous.
	The presentation concrete, precise and avoids extraneous information.
	The vocabulary and linguistic expressions used are rigorous, comprehensible and adapted to the students.
	The chosen video originates from a reliable source (institutions, validated academic platform).
	The questions added using Edpuzzle encourage student reflection.
	The questions incorporated with Edpuzzle reinforce the key ideas presented in the video.
	The audio notes incorporated with Edpuzzle complement the explanations of the chosen video.
V-D4. Aspects of math instruction	The video presents concepts in math, algorithms, and problem solving.
	The video links math concepts to problem solving.
	The math content is presented in order of increasing difficulty.
	Math content is linked to real-life scenarios or other subjects.
	The video links the math content with the historical role math has played in human development.
	The video stimulates the development of the math competency.

Appendix B

Table A2. Results of the Spearman Rho test used to assess possible correlations between the video scores and associated dimensions and the TDC self-assessments and associated dimensions D1, D2, D3, D4, and D5, and associated sub-dimensions D1.1, D3.2, and D3.2.

Variable	TDC	D1	D1.1	D2	D3	D3.1	D3.2	D4	D5
Video	−0.02	−0.01	−0.01	−0.04	0.06	0.05	0.12	−0.07	−0.04
V-D1	0.00	0.00	0.07	−0.02	0.08	0.06	0.11	−0.07	−0.02
V-D2	0.04	0.03	0.03	0.07	0.02	0.02	0.07	0.03	0.03
V-D3	−0.07	−0.07	−0.11	−0.10	0.01	0.00	0.05	−0.12	−0.09
V-D4	0.03	0.06	0.07	0.00	0.11	0.12	0.17	0.00	0.02

No results with p-value < 0.05.

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