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The Construction of Knowledge for the Teaching of Sciences: A Reflection Seen From the Pedagogical Content Knowledge (Pck)

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Abstract

This paper presents the conclusion of a research project developed by the authors, as well as the continuation of previously published works between Panama and Mexico. The project was divided into three stages: 1. a framework was proposed for developing a test to characterize the Pedagogical Content Knowledge (PCK) construct in secondary school teachers; 2. An updating course was designed and given to practicing science teachers (mathematics and physics), focusing on their PCK as the central axis; 3. finally, the last phase of the project consisted of the implementation of the course and the analysis of how activities affected PCK according to what the teachers indicated. This work has a qualitative analysis approach and aims to present the main results derived from this implementation, where it was concluded that according to the findings of this study, a) the use of two digital tools helped to modify the PCK, and b) the importance of implementing episodes of reflection on their teaching practice for continuous improvement.

Keywords: *Pedagogical Content Knowledge; Physic Teachers; Updating Course, high school education; Educational System*

After COVID 19 pandemic, one important challenge to educational system around every country is solve the question, how we can improve the teachers training programs? Especially programs directed to high school physics teachers.

Diverse research shows that teachers in general and physics teachers in particular have not the competences and digital abilities to face the challenge of teaching in digital environments. In this sense the authors propose one alternative to design teacher updating course focus to improve the Pedagogical Content Knowledge to small group of physic teachers, using systematically digital tools. Digital tools as GeoGebra and Tracker were popular resources during pandemic due to its characteristics, and after pandemic time still being adequate resources to improve teaching competences. In this work we present results of implementing one updating course to physics teachers focus in kinematic graphics.

In Mexico there are Universities that offer a bachelor's degree in physics, and to date there is no Bachelor's degree program that simultaneously integrates training as a physicist and training in Physics teaching, with the profile for future High School Physics teachers. However, programs are offered at the level of diplomas, masters, and doctorates in science education

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(Physics or Mathematics or Chemistry) [1–4]. In Panama, there is a degree in Physics Teaching, with a duration of four years offered by the Faculty of Exact Natural Sciences and Technology of the University of Panama. This Faculty also teaches the Physics Degree and once the subjects are finished, the interested party has the option of enrolling in the Faculty of Education Sciences and after two years receives the title of Secondary Education Professor with Specialization in Physics. In other words, there are two options for the training of future High School Physics teachers [5]. Both in Mexico and Panama, they also teach Physics courses at the high school level, engineers, mathematicians, biologists, chemists.

Given this type of initial training, it is often mistakenly assumed that in-service teachers who teach physics courses have a deep knowledge of the discipline and that, consequently, what they require are updating courses in general pedagogy, that is, programs on educational models, for example, on teaching skills, courses on didactic strategies, courses on the use of didactic resources, etc. Moreover, the institutional strategies that are usually implemented for teacher updating usually consist of offering this type of course to all teachers equally, regardless of the discipline they teach. In this sense, physics, mathematics, and biology teachers must attend to these updating processes.

In this order of ideas, this research project adopted the premise that specific didactics are a viable option to promote updating processes in in-service teachers, and it was assumed that the Theoretical Construct called Pedagogical Knowledge of Content (PCK); (in Spanish also denominated CDC by its acronym), provides theoretical and methodological elements that can contribute to the design of updating courses.

Since a test was designed to characterize the *PCK*, which was already published in a scientific journal [1], and from this characterization it was possible to design learning tasks that made up a teaching update course. , whose design was published in another scientific journal [3,6]. The final phase of this project consisted of implementing the ten tasks that were designed with a group of 15 professors who taught physics courses at the high school level. Transcripts of the videotaped sessions were made, furthermore, the test was applied at the end of the course to characterize the *PCK*; in the following sections, the analysis of said implementation and the main findings are presented.

1.1. Theoretical References: Teacher Training and Updating Programs in Mexico and Panama

In the case of Mexico, the training and updating of teachers, particularly university students, has been manifested by the financing that the educational authorities have granted for the creation of postgraduate degrees (mainly master's degrees in education), and in the financing of training courses for university professors. Additionally, the use of technology in education is relevant for enhancing students' and teachers' teaching and learning processes [7–9]. However, the scarce research and reflection that Mexico has had on the training of university teachers make it impossible to know what scope and/or benefits these policies have had [10].

For Panama, the study programs for the bachelor’s degree in teaching mathematics and physics by the University of Panama have a common trunk in the first year. The last continuous training course was by SENACYT where topics on didactic strategies and resources for the use of information and communication technologies, astronomy, classical physics, and modern physics were discussed. It sought to encourage teachers to assume their role as researchers and knowledge generators from the teaching activity.

In this order of ideas, Torres et al. [11] mention that in teacher training, "the disciplinary knowledge of the teacher is mostly valued, undervaluing the knowledge of a pedagogical type, more closely related to teaching itself" (p. 296), then, in the case of mathematics teachers, as an abstract science, it is believed that university professors, tend to consider more generic elements, likewise to responding to an excessively instrumentalized vision of them, giving scientific rationality, to theory over practice, so that the reflective dimension, the pedagogical dimension, and "in general, elements and aspects of the profession of teaching, as well as the personal sphere of the teacher, has been neglected, who considers him as a subject who has expectations and needs" (p.296).

Being able to identify specifically what training and / or updating programs for physics teachers of baccalaureate or university level exist, is even more complex, there is no doubt about the existence of these in some educational institutions, but in any case they are isolated facts that have been little investigated and reported in the literature to have evidence on the theoretical references that have been adopted for their creation and there is no data on the results of these programs to know their efficiency.

In this regard, Caballero-Sanchéz [12,13] , mentions the importance of high school teachers (also known as upper secondary level in Mexico) being constantly updated, given their initial training. Regularly teachers who work at the level of upper secondary education or baccalaureate have not been trained for teaching; almost all are graduates of universities. There are lawyers, chemists, doctors, architects, etc., however, they can and should be up to date with the new educational trends that allow the acquisition of better knowledge in students, since they have acquired a social commitment: to educate and transform students who will become citizens who will enter the work area or who may be taking a university career.

For the purposes of this research, it was considered that the CONSTRUCT of the PCK provides guidelines for the design of training and / or updating courses for teachers of Physics, as discussed in Campos-Nava & Ramírez-Díaz [14], five dimensions were identified that characterize this construct, which allows to form an amalgam between the disciplinary and pedagogical knowledge of the teacher (See Figure 1).

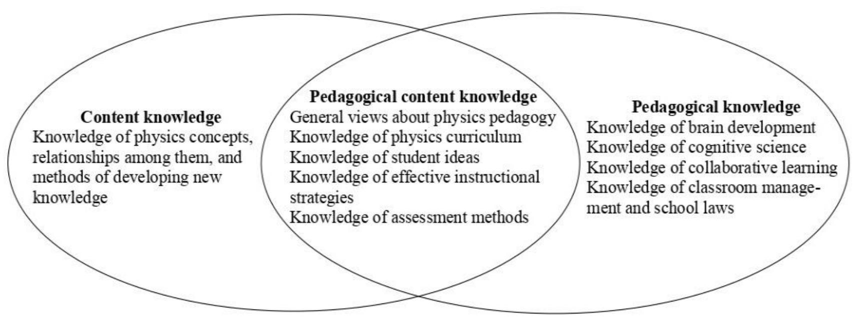

Figure 1: Pedagogical Knowledge of the Physics Teacher's Content (Taken from Etkina [15].

In this sense, Merino de la Fuente [16] affirms that being a good physics teacher implies not only knowing the subject in depth but also having skills in didactics and pedagogy and having the aptitudes and attitudes of a researcher. Physics educators ought to be proficient in physics, and didactics, including teaching, as well as possess flexible perspectives, which is compatible with the construct of the PCK. The National Research Council [17], mentions that science teachers must have a solid framework in learning theory to comprehend how the acquisition of knowledge occurs and takes place and the way this knowledge is promoted, alongside a thorough understanding of science, which is also in accordance with the concepts handled by the PCK construct.

In this regard, Bromme [18], reports the results of a comparative study between experienced teachers and novice teachers, coined the term expert teacher, to refer to those who have accumulated throughout their career, the experience that allows them to make better decisions in their teaching work either when planning the class or when identifying the difficulties that students are having to understand a topic of the class, to mention two examples. This type of teacher does not directly follow the strategies that have been taught in his pedagogical training but builds his own strategies; the reflection of his practice becomes fundamental to achieving progress in their professional knowledge, which is an unusual trait in teachers considered novices. in this sense, a teacher may have years of experience as a teacher, but the scarce reflection of his practice can keep him in a rookie stage, in other words, the years of experience as a physics teacher do not necessarily contribute to the teacher being an expert; but rather the deep one reflection on their teaching practice.

In line with the above, NRC [17], states that educators' learning is similar to students learning since it demands teachers to formulate inquiries, provide solutions to those concerns, assess the material acquired, provide applications, and integrate with novel knowledge in the context of science education. Professional knowledge is critical for science teachers in basic education, as it facilitates them to teach effectively and to offer their students meaningful and long-lasting knowledge. According to authors such as Hall & Simeral; Kulgem eyer & Riese [19,20], professional knowledge includes declarative knowledge, which is an understanding of the facts, concepts, and theories in a subject, along with procedural knowledge, which is an understanding of how to do something. Both types of knowledge are of equal importance for science teachers. In addition, procedural knowledge enables teachers to lead their students in critical thinking and problem-solving processes and provides them with an appreciation of how concepts and theories are applied in real scenarios. According to authors such as Cochran-Smith & Zeichner [21], this procedural knowledge is essential for teachers to develop critical thinking and problem-solving skills, as fundamental sub-competencies of complex thinking for the 21st century [22] in their students and helps them gain an insight into how science relates to the real world.

It is clear that the processes of training and updating of Physics teachers that exist (although as already mentioned few compared to those of another nature and rarely reported in the literature), hardly consider amalgamating both types of content (disciplinary and didactic) into one, to offer courses of didactic-disciplinary content for physics teachers; In this sense, the PCK offers possible alternatives to design this type of courses, since recurrently as stated in previous paragraphs, it is emphasized that teachers must develop a Didactic Knowledge of the Content they intend to teach [23]. Additionally, Etkina [15] states that future physics teachers should practice in classroom conditions comparable to those they will be responsible for creating; furthermore, to the fact that future educators in physics ought to pursue physics in a comparable manner that they would teach it. Although these statements are aimed at the training of new physics teachers and not at updating the teachers in service, we can consider them equally valid for those active Physics teachers, who nevertheless due to the circumstances have had little didactic training in the discipline, that is, they could be considered novice teachers.

In the same order of ideas, McDermott, Shaffer, & Constantinou [24] mention that some of the courses offered to train future teachers of Physics, "perceive the discipline as an inert body of knowledge that only has to be memorized, and not as an active process of inquiry". (p. 412) and ensure that standard courses do not provide the kind of preparation teachers need. They also state that teachers usually instruct in the same manner in which they were educated; assuming they were instructed using readings, they would rather impart knowledge through readings, regardless of whether that method is unsuitable for their pupils, in this context, educators must be ready to discern between inferences and observations and use their knowledge and presumptions to draw reasonable inferences [24]. Therefore, the development of pedagogical knowledge of the content by teachers reflects what we know about student learning; it can be fully developed only through continuous experience. However, experience is not enough. Educators must also have the possibility to analyze elements of science using pedagogical knowledge of content, acquisition of knowledge, and instructional design, along with establishing interactions throughout these elements [17,25,26].

After careful consideration of the concepts and literature reviewed in this research, it can be inferred that the dimensions used to characterize the declarative pedagogical content knowledge (PCK) of a specific topic within the discipline of physics can serve as a useful guide in designing a training course aimed at promoting the development of this construct in physics teachers across various topics in the field [27,28]. For instance, the dimensions identified in the study can be applied to design a training program focused on enhancing teachers' PCK related to kinematic graphics, which was the topic of investigation in this study.

1.2. Digital Tools to Teach Physics

Regarding the research that reports the results of using some digital tools for the training of physics teachers, is scarce compared to other lines of research; however, it is considered essential to incorporate them into the processes of training and updating them. Suppose the technical aspect focused on the use of technologies such as cell phones and computers is taken. In that case, it is a fact that the use is very limited, mainly because teachers do not know the scope of the use of these tools applied to education [...] [29]. In accordance with the above, Ramírez-Díaz [30] states that: In order to keep their teaching skills current and to improve their instructional practices, physics teachers need to have access to ongoing training programs that provide them with updated knowledge on teaching methodologies, pedagogical principles, and the use of instructional resources and technology. This training should help teachers deepen their understanding of the fundamental concepts and principles underlying effective teaching approaches and enhance their skills in designing and implementing effective instructional strategies and using appropriate tools and resources.

Since they are official requirements that teachers make use of ICT, it is expected that a high percentage of active Physics teachers, at some point have received some course on the management of resources such as management of interactive electronic whiteboards; design of electronic presentations in PowerPoint; management of social networks such as Facebook; design of courses in educational platforms such as Moodle; or creation of MOOCs (Massive and open online courses). However, suppose there is no clear pedagogical intention in the use of these technologies. In that case, their use may result in a passing fad or have an objective of a merely instrumental nature, so in some cases, the same teachers consider them ineffective to improve their practice, so they could have little use and positive effect in physics courses. This leads teachers to consider that their updating needs including the use of digital technologies for didactic purposes are not satisfactorily covered, leaving a feeling that the updating processes are disconnected from their real practice. In this regard, Hirsch [31] indicates that teachers who have participated in training courses often express the need for activities that are more relevant to their actual teaching practice, as opposed to the generic activities that are commonly prescribed by institutional training program designers and researchers. These teachers note that, when training activities are designed with their interests in mind, they may not fully address their specific needs and requirements. As a result, it is important for training program designers to take a more thorough approach to understand the significant demands and expectations of teachers when designing effective training activities.

In this sense, two digital tools (GeoGebra and Tracker) were chosen because they were considered linked to the interests that Physics teachers who teach the topic of kinematic graphics may have and could even favorably influence the teaching of other topics of Physics [32]. This teaching approach can be coupled with the use of digital tools for the physics or mathematics class, a situation that has been recommended by different researchers, which point out some of the possible benefits of this combination: in general, we can affirm that it offers new opportunities to raise and discuss problems since it allows a different "empirical and visual approach that in turn can contribute to a better understanding of the problem in the studio" p. 111 [33]. Moreover, some authors identify those digital tools can even serve as cognitive tools and not only amplify but reorganize cognitive processes in the student [34], because they allow to reinforce several of the processes of mathematical thinking, such as visualizing, experimenting, corroborating, analyzing, reflecting, performing tests and demonstrations, [35,36].

As mentioned in the introduction, the design of the ten activities of the training course [3] was already reported in a previous research paper, which can be consulted directly through the following link: https://bit.ly/33MGSeh

In the following section, the methodology used to analyze data obtained from in-person work sessions conducted with 15 active high school physics teachers is presented.

2. Materials and Methods

Once the specific topic of kinematic graphics was chosen and the participants' characteristics in a training course with this theme were determined, it was decided that the chosen sample was for convenience. The participants should be teachers in service who taught Physics at the baccalaureate and/or bachelor's level, particularly who had previously taught the subject of mechanics, it was decided that the participants were all belonging to the same educational institution, although from different campuses, this for the facilities granted by the institutions to summon their teachers. An open invitation was made to which 25 teachers originally responded with interest, however, only 15 were presented to the training process. In this order of ideas, Álvarez-Gayou [37], states that: "In qualitative research, representativeness is not of interest; research can be valuable if it is done in a single case (case study), in a family or in any group of a few people" (p. 33).

Subsequently, the structure of the course was designed, consisting of general objectives, objectives per session and topics to be discussed in each session. It was determined that the process had a temporality of 5 days, having a daily session of 4 hours, the above mainly for administrative reasons because the professors who would attend would have to attend other institutional activities within the same period since it was proposed for the inter-semester period, the above because, during that period, teachers are exempt from attending to their groups. However, they must attend other assignments such as the teaching of advisory, application of extraordinary exams, attendance at other institutional courses, and collegiate works of academia among others; and for curricular assessment purposes, in the institution to which the teachers belong, the minimum number of hours that a training course must have must be 20 hours.

Regarding the content of each session, it was decided that teachers should participate in reflection exercises on their own teaching practice, so, for the first session of the course, a battery of questions that were asked at the beginning of the process in plenary was designed.

For the reflection exercise in subsequent sessions, readings were sought (mainly journal articles or conference papers), which they were asked to read in advance, so that, at the beginning of each session, the relevant topics they identified in each reading were discussed, in this sense, Caballero, [12,13] points out that he field of education must prioritize a process of critical self-reflection among teachers, as it is a fundamental aspect of the practice of accounting for one's work. This reflection should lead to thoughtful and critical action, which can be followed by a reorientation of training programs to better serve as a tool for improvement rather than a bureaucratic burden. By engaging in this process of reflection and modification, teachers can better understand their own thought processes and behaviors while carrying out their duties, ultimately leading to meaningful improvements in their work.

From the perspective of various researchers, when interacting with a group of individuals to discuss in depth some topics in a structured way to be able to investigate their experiences and beliefs, the focus group is being used as a qualitative research method. Consistent with this perspective Álvarez-Gayou [37] describes that the focus group discussion is a social research technique that prioritizes verbal communication and aims to facilitate interactive conversations about a particular topic or research object within a specified time frame. This technique's primary goal is to capture individuals' perspectives, emotions, and experiences within a group setting. Although the author himself emphasizes not to confuse this technique with participatory workshops, it is considered that, for the purposes of this research, at the beginning of each session, when a discussion was made in plenary, either discussing some reading material left previously for review, or the questions that the researcher asked the participants in the first session, served as a focus group.

It is convenient at this time to list the questions that were asked in plenary at the beginning of the course, with which it is intended to generate the reflection of the teachers on their teaching practice, in addition to trying to identify some aspects of the declarative PCK of them:

- What does it take to be a good physics teacher?
- Can I improve my teaching practice? In what way?
- Has the way I teach my classes changed over time? In what way?
- Have I incorporated new teaching resources for my Physics classes? Which ones?
- What are the teaching resources that I use the most? Why?
- Do I need to know my students better? What kind of students are they?
- What kind of mistakes do students make most often? Can I detect them? How do I try to prevent them from being committed?
- What topics of the Physics I (Mechanics) program do I consider less important? Why?
- What topics do I consider most important? Why?
- How do I evaluate my students? Has my way of evaluating them changed over time?

The intention of starting the training process by posing these questions in plenary to teachers, as already mentioned, was on the one hand to encourage reflection on their teaching practice, and on the other, to try to identify aspects of the teachers' declarative PCK around Physics; furthermore, to the fact that it is compatible with the objectives of forming a focus group as a qualitative analysis technique; in this regard, Álvarez-Gayou [37] states that: "The focus group aims to provoke confessions or self-presentations from among the participants, in order to obtain qualitative information from them on the research topic" (p. 132).

In this vein, the questions were written after reflecting on the five dimensions of the PCK that were defined in previous work: i) Knowledge and beliefs about the physics curriculum; (ii)

Knowledge and beliefs about difficulties in teaching a specific topic of physics; (iii) Knowledge and beliefs about the preconceptions and previous ideas that students have in a specific topic of physics; (iv) Knowledge and beliefs about the use of didactic resources and strategies to teach a specific topic of physics; v) Knowledge and beliefs about the most effective way to evaluate a specific topic of physics [14,38], furthermore, to being consistent with what is intended from the work with a focus group, as Álvarez-Gayou [37] argued before it's essential to understand that the primary goal of a discussion group is not to arrive at conclusive answers or unanimous agreement but to foster collaborative dialogue and exchange of diverse perspectives on issues relevant to the research objectives. In essence, the focus is on facilitating an open and inclusive discussion that allows for a rich exploration of ideas and insights from the participants.

The training course that was designed, also considered elements of the methodology called Teaching Physics by Inquiry, (physics by inquiry, [39], for this reason it was decided that the content of the activities that were developed during the course, had as a central axis the interpretation of graphs of kinematic variables and that it was also proposed as part of its development, the use of the two digital tools already mentioned at the beginning of this proposal (GeoGebra and Tracker), since it was considered that with the use of these resources episodes of inquiry with teachers could be promoted, beyond a transmission of knowledge in a traditional way. The intention of teachers to engage in activities of this nature is due to the agreement with the approach of various authors, who affirm that teachers should receive training, with processes and strategies similar to those that would be intended for them to put into practice within their classrooms. It is widely recognized that science education for young learners is most effective when it is grounded in tangible experiences that provide the basis for developing scientific concepts. Similarly, researchers, including ourselves, have found that this same approach is highly effective when teaching adults, particularly when introducing new topics or approaching familiar topics in a novel way. By providing concrete, experiential learning opportunities, adults can build upon their existing knowledge and form deeper, more meaningful connections with the material [39].

Assuming that teachers would not have to be familiar with GeoGebra and Tracker, it was decided that each 4-hour session should be divided into two moments: i) A first moment when working with the SGD GeoGebra (first two hours of each session); (ii) A second moment in which to work with the Video Analysis Tracker Software (last two hours of each session) and the use of pre-recorded video analysis software for the measurement and analysis of variables, especially linked to movement [40]. It was decided that to manage the course, a microsite hosted on the Google platform would be used as an additional resource, in order to share everyday readings in electronic format that teachers should do extra classes to discuss them in plenary in the next session (focus group), this resource was also used to share for each session the videos that teachers would have to analyze with the Tracker software, it should be noted that this site was fed back day after day, that is, not all the resources and reference materials appeared at the same time; it was taken advantage of the fact that there was a computer laboratory with internet and with GeoGebra and Tracker already installed (management carried out by the instructor-researcher previously), so it was known in advance that at the time of addressing an activity with Tracker, teachers would have the possibility to access the site at that time and download the required video.

For the purpose of consultation of those who are interested, this microsite will be unchanged indefinitely and its final version can be accessed if desired, through the previous link (The link to access the microsite is as follows: https://goo.gl/C9X6AP)

Figure 2: Google Micro Site View Used to Manage Course Materials.

For the first session of the course, together with the aforementioned reflection exercise of the beginning, it also consisted as mentioned of two activities that were considered introductory to the use of both digital tools, in total, due to the program of the course, it was required to design 10 activities in sum, 2 for each session, the activities should affect one or more dimensions of the PCK of the teachers in the interpretation of kinematic graphics. To exemplify the above, an excerpt from Activity 2 of Session 1 is presented (For more details see https://bit.ly/33MGSeh):

Activity 2: Analyze in Tracker the movement of a cart with constant speed.

Objective: To introduce teachers to the use of Video Tracker Analysis software by means of the analysis of the video of a toy cart that moves at a constant speed, and generate the graph position against time and speed against time.

For this activity, you can start with the initial question: in what situations does an object move at constant speed in a straight line? This is an invitation to remember Newton's first Law, however, it is about thinking about situations that are not necessarily found in nature, for example, a person traveling on escalators of a shopping mall is an example of a situation in which an object moves at approximately constant speed and in a straight line. As can be seen, the activity inherently involves disciplinary knowledge beyond the interpretation of graphs, it also encourages the reflection of the teacher on the analyzed phenomenon and it is requested that an analysis be made by means of a video, using a digital tool, so that by itself it values the cognitive processes that are put into play when simultaneously the video of a moving object can be observed while generating its kinematic graphics.

As an instrument for collecting information, it was chosen to video-record each session of the course, by means of a video camera, placed in a fixed way on a tripod in a corner of the room, the researcher-instructor made sure to make recording tests prior to the start of each session and ensure that the video-camera operated properly, recording continuously during the sessions. Authors such as Álvarez-Gayou [37]suggest that the researcher record audio and, if possible, video of the sessions with focus groups, and that the researcher also takes field notes, to later contrast the two sources of information [...] Video recording offers many advantages: less effort to capture everything, easy review of group interaction as many times as you want to analyze, and certainty of having all the information, although with it the cost of operation increases p.141 [37]. In the case study, it was not possible to take field notes, the information analyzed comes exclusively from the videos and the application of a test (the GC-PCK questionnaire) answered by the participating teachers at the end of the course.

Other authors such as Taylor and Bogdan [41], point out the unwanted effects on the participants of qualitative research, by introducing a means of mechanical recording of information such as the video camera; in the case of this work, it is considered that this element of distraction is also generated when the participant in advance knows that an observer is recording notes of what he does and speaks. As already mentioned, despite this possible drawback, the researcher did not have the possibility of taking field notes and his viable option for recording the data was through video recording. Participating observers seem divided as to the convenience and inconvenience of taking notes and employing mechanical devices in the field. Some observers understand that intrusive logging devices unnecessarily attract the observer's attention and disrupt the natural flow of events and conversations on stage p. 79 [41]. On the other hand , Martínez [42] is also in favor of using a means of recording such as the video recorder in qualitative research, also assigning features of validity to the information thus obtained: Currently, the researcher with qualitative methodology, to facilitate the process of structural corroboration, has two very valuable techniques: triangulation (from different data sources, from different theoretical perspectives, from different observers, from different methodological procedures, etc.) and audio and video recordings, which will allow us to observe and analyze the facts repeatedly and with the collaboration of different researchers, p. 88 [42]

Another rationale for using a video camera to record information is that it is arrogant to believe that the researcher's memory is so good that he will be able to recall everything that happened during the sessions and fill his field diary a posteriori. Regarding using mechanical means for recording information, Mcmillan & Schumacher [43], are also in favor of using them and consider this way of collecting the data, as a source that promotes the study's validity. They also state that in order to improve the validity and usefulness of data collection, researchers often turn to tools such as recorders, cameras, and video equipment to capture a detailed and accurate record of the research process. However, it is important to recognize that the data recorded through such equipment is not immune to external factors that may influence its quality and interpretation. Such factors may include the technical specifications and limitations of the recording equipment, the angle or distance from which the recording was made, and the potential social impact of the equipment on the research context and participants. By carefully observing and accounting for these factors, researchers can enhance the validity and accuracy of their data, ultimately contributing to more robust and reliable research findings.

In the study presented, the recording of the information was carried out, as already mentioned, with a single video camera, within a closed classroom that allowed to have relative control over environmental aspects, in the case of producing a negative influence such as those that Taylor and Bogdan [41] mention, we consider that the influence of the device on the natural flow of events is minimal, since most of the time, the researcher was the first to arrive on stage, place the equipment in a discreet place and trigger the video recording, even before the participating professors began to arrive. After the implementation of the course, we proceeded to analyze the information obtained from the group of teachers in different episodes, for this purpose the video recordings of the sessions were analyzed.

The transcripts of the working sessions with the participants were divided into two moments or stages that are considered equally relevant: i) The beginning of each session, in which using the methodological technique of focus group, various topics related to the interpretation of kinematic graphs were discussed with the participants, with which it was intended to inquire about the declarative PCK of these; (ii) The work of the teachers with the learning activities, the transcripts of this stage are not complete, since at various times, the dialogues are about technical aspects of the management of the software, with this analysis it was identified if the design of the activities was pertinent and if the use of the resources influenced the declarative PCK of the teachers.

3. Results

A training course was designed for teachers, focused on the dimensions of the PCK that were adopted in the previous stages of this study [14]; the sessions were videotaped, and transcripts were made of the first minutes of each session, in which discussion groups were held in plenary, whether they were questions that the researcher proposed or questions about readings of materials that the researcher provided.

15 teachers were enrolled in the course, although only 14 of them were recovered data. In the transcripts, they are identified as P1, P2, P3, ..., P13, P14, P15. There were 4 women and 11 men who participated in the training course, all of them high school teachers dependent on the same public university, although from different campuses.

The ages of the participants ranged from 31 years, the youngest to 56 years the oldest teacher. The average age was 40 years. A particularly relevant fact is their teaching experience; in this case, there were teachers with experience of just one and three years at the time of carrying out the course, until the case of those who had 23 and 28 years of teaching experience in Table 1 you can see a general summary of the data of the participants.

As for their vocational training, only 13 participants were recovered; 10 professors are engineers, 2 have degrees in chemistry, and one has a degree in Physics; all have taught mechanics at the baccalaureate level. Of the 14 professors who provided their information, 7 reported having postgraduate studies (either a specialty or a master's degree), and the rest said they did not have any.

Table 1. Summary Of Participants' General Information.

Teacher Id	Age	Initial training	Years of experience
P1	35	Industrial Engineer	4
P2	33	Degree in Physics	1
P3	47	Degree in Chemistry	23
P4	36	Degree in Chemistry	9
P5	N/A	N/A	N/A
P6	43	Industrial Engineer	3
P7	47	Industrial Engineer	5
P8	37	Electronics Engineer	9
P9	56	Industrial Engineer	28
P10	34	N/A	6
P11	44	Industrial Engineer	3
P12	41	Electronics Engineer	8
P13	40	Mechanical Engineer	5
P14	35	Electronics Engineer	5
P15	31	Geology Engineer	3

The intention of the analysis was to identify if the teacher's manifested episodes of reflection on their teaching practice and if, during the interaction with digital tools, it was possible to identify indications that they influenced their PCK.

The transcripts were analyzed using double-entry tables, in which the dimensions of the PCK intersect, with possible evidence of reflection on its teaching practice and incidence in its own PCK, by including the dialogues that they manifested.

As already mentioned in the methodology section, the five work sessions that were held with the Physics professors were video-recorded, and transcripts of them were made and analyzed in the light of the elements proposed in the theoretical references, the above in order to identify findings that allow corroborating that there was a favorable impact on the PCK of the teachers, in addition to being able to detect other additional findings that were of interest.

The analysis was conducted by paying attention to the following categories that emerged from the analysis itself, as well as from the conceptual framework and literature review:
Evidence of influence on any of the dimensions of the PCK.

Table 2. Analysis of the Effect of Geogebra and Tracker in the PCK.

The Use of the Chosen Digital Tools Promotes the Development of the PCK.	Transcript Excerpt	Comments on the Analysis.
Session 2: Activity 1 (Part 1). PCK Dimension: Knowledge and beliefs about the difficulties of teaching a specific topic of Physics.	*Instructor*: Look, here, the advanced student is done! [Refers to the teacher P*2* has also made the representation of the kinematic graphics] *P2*: [Laughs] I went ahead; I already knew what I had to do. *Instructor*: How did you do it? With a geometric place like yesterday? *P2*: This part is with the geometric place, but for example, I quote it, and my point of interest was this, right? *Instructor*: Exactly! *P2*: So, with a geometric place, I didn't have to put the function, but then it won't let me find the intersection... *Instructor*: Okay, and is that when the graph of the geometric place of one of the objects intersects with the other, it has to be the solution we are looking for, the positions are the same, and according to their shapes, they can only intersect once, they cannot find the two objects again ... *P2*: Well, if the equations were solved, there would be two solutions... *Instructor*: But what does that mean? If you realize it would be for a negative time, and that would mean the time in which the truck passed through where the car was at rest... the other question, to know the speed at which the car goes when it reaches the truck, without the student doing complicated things, how does it occur to you that you could explain so that from this he knew the speed? *P2*: Oh, okay, it has to do with the slope at that point... [Inaudible] *Instructor*: And then you could already tell the student about the slope of the tangent line at a point on the position versus-time graph; you could tell him about the instantaneous velocity for that time.	Using GeoGebra to create a particle simulation with MRU and MRUA and visualizing the position versus time graphs of both in an additional graphical view, allows teachers to relate the phenomenon to their graph. In this case P2 denotes a considerable advance in the use of the digital tool. It is able to anticipate what follows from the task and reflect on the difficulties that students may have to relate the slope of a tangent line with the instantaneous speed.
Session 2: Activity 1 (Part 2) PCK Dimensions: Knowledge and beliefs about the Physics curriculum. Knowledge and beliefs about the difficulties of teaching a specific topic of Physics.	*Instructor*: [...] The second part is to open a graphic view two, and in that graphic view two, what we have to do now is a graph, if you remember yesterday's exercise, in this graphic view two what I want to see is, now in the axis "Equis" has as a domain time, and the axis "ye" would be the position for example of the truck, I want to see here now the graphic of the truck, its kinematic graphics [...] However, the car that chases no longer has uniform rectilinear movement and no longer has to see a straight; we would have to see . *P9*: A curve, because one goes like this and another like this. *Instructor*: A curve would have to be compatible with what we see here on the left side [refers to the simulation of the chase]. That is, the curve would have to be like this, time goes by, and it is advanced little by little... and the other one is why it takes advantage because it always goes "even" [refers to constant speed]. We want to see where they intersect because there is an important meaning in the crossing of the two graphs ... what would the crossing of two graphs of position against time mean? [Silence] [...] and then the student should understand that objects that move with uniform rectilinear motion, with constant velocity, their graph should be a straight line like this, because they travel equal distances at equal time intervals, which is what we tell them when we explain uniform rectilinear motion. *Instructor*: [...] and see if you agree with me, if we just present this [refers to the position versus time graphs of both objects] and ask you how each object moves, many students may think, because if this is the graph of its position and I see this straight line, I think that the object moves as in a ramp, and this must be like a parabolic shot teacher, because I see it as a parable, and it turns out that no more, it turns out that the two objects move in a straight line with the same trajectory, just that one moves with constant speed and another with constant acceleration [...] How could you explain to the student what he can do to know the speed of the car when it reaches the truck? Remember that this is the graph position against time [Silence for several seconds], so what speed was the car carrying? *P9*: Well, where they are with that time, calculate the speed. *Instructor*: Calculate it? No! How would they get it from there? [Refers to the position graph] that is, graphically, where the speed is [Silence for several seconds] *P2*: Well... I can think of something... but I don't know if the student could be upset more... and I don't know if maybe use the concept of limit a little bit, put maybe very close, but not that they are together, right? but very close to point A and point B, the point of the truck... and that from there they trace me a straight, and the slope of that straight would have to be the speed or almost the speed of the truck . *Instructor* [...] we can draw tangent lines to this curve at different points, and the tangent straight at this point, well, the slope of that straight is the speed that the car carries at that moment [...] If we trace the tangent lines, we see that as time passes, they are tilted more, that is, the car takes more and more speed . *P11*: There the detail is that we see these issues with students in third [refers to the third cycle or semester of high school] *Instructor*: And they have not seen anything of calculation ... then there would have to look for a strategy so that without giving the concept of derivative, yes explain it that if you draw tangent lines, from there you could get the value of the speed [...]	Again, the use of GeoGebra to create a motion model and to be able to observe kinematic graphics at the same time, allows teachers to reflect on the possible difficulties that students have to interpret kinematic graphics, likewise to identifying that some topics of the mathematics curriculum contribute to the interpretation of kinematic graphics.

Table 3. Analysis of the Effect of Tasks Designed at the PCK.

Impact of the Learning Task on PCK Dimensions	Transcript Excerpt	Comments on the analysis.
Session 1 Focus Group. PCK Dimension: Knowledge and beliefs about the Physics curriculum.	*Instructor*: [...] remember that this course is focused on a very specific topic of the Physics 1 of the mechanics' course, so of that Physics program that you know much better than I do, even what topics do you consider less important? *P2*: I think it's even lacking. *P5:* I'm there if I don't know... many say _*it is missing*_, but that of saying is missing, so how is it that the end of the semester arrives and they do not end [...] *Instructor*: [...] So what topics of the mechanics' syllabus do you consider of greatest importance? *P3*: [...] vectors, because with vectors they learn movements, electricity, and optics. *Instructor*: [...] any others you consider? [In Unison: Unit Conversion] *P 14*: Strength, power, and energy. [In unison) Dynamics]	Start the first session of the course with a series of questions that motivate reflection, allowing us to identify that some teachers have developed the declarative PCK in the corresponding dimension.
Session: 2 Focus group. PCK Dimension: Knowledge and beliefs about previous preconceptions and ideas that students have in a specific topic of Physics.	*P9:* I found that teachers who have the contents and pedagogical skills are not always going to be good teachers, but there is a pedagogical knowledge of the contents; what does this mean? The PCK, that we must have the ability to transform that knowledge so that it is attractive to the student, ask us questions of what is the intentionality of teaching a subject of a subject? And to see that the student is motivated by wanting to learn, and also very careful in what are the "false contents", the false ideas, because we can have one conception ourselves, the knowledge another, and transmit false contents ... and it also says that we must have what is the... I would call it the transversality between what is the historical, philosophical, technological question; that this subject in particular [...] *P11: [...]* several professors I had come to mind, precisely in this disciplinary knowledge and pedagogical knowledge [...] showed very direct examples of the company, for example, I remember in ... in hydraulics, right? in hydraulic machines... I remember that I didn't understand him, that is... I don't know if there is... I said precisely; there was no lack of that transformation that the article says, precisely I said because there the teacher lacked that transformation, pedagogy, because knowledge was very much to spare, right?, very much ... he told us that he had designed hydraulic machines and more... but already in the part of the transformation it was very complicated [...] I didn't have that preparation, that pedagogical training, and then I said, well, what you have to look for is... in a way, to get on this side as a student, to see, ah well, let's see this issue, how I have to transform it, or what activities that really are in the benefit (of the students) [...] well, to me... the truth then it can cost me work, I do understand it (disciplinary contents). Still, I do not know, how I explain them [...] well, I am what I have tried to do with my students, how to explain to them, right?, how to explain and take them to something so real [...] as you said yesterday, the fact of playing with two faces, and discovering the formula of something technical, that could be carried so thoroughly or so superficially.	Starting the second session by discussing a couple of readings that were read from homework, have allowed teachers P9 and P11 a deep reflection on the need to convert the disciplinary knowledge that the teacher has into something teachable (PCK), even P11 alludes to one of the activities that were done in session 1. P9 for its part has identified the concept of alternative ideas (what she calls false content) and considers that it is important to identify them in students, evidencing that it is influencing the dimension of the PCK on alternative ideas of students.

Table 4. Evidence of the Need for Greater Disciplinary Knowledge of Teachers.

Need For Greater Disciplinary Knowledge On The Part Of The Teacher	Transcript Excerpt	Comment
Session 2 Focus Group: Knowing Physics is necessary, but not enough to teach it. PCK Dimension: Knowledge and beliefs about the difficulties of teaching a specific topic of Physics.	*P5*: What happens is that there is a very interesting thing, they say it here (refers to the article), when the new teachers, who are arriving, because logical is, that to finish soon, ALL and I dare to say that all of us who are here or most of us think we study in some university, if not in this one, when we were students and when we were about to leave, what we thought was never to teach, the idea of us was to go to a company, go somewhere else, because in pedagogy, we were not taught because it is not the program (it refers to the graduation profile of what I study), it does not bring anything of pedagogy of any program that is Physics, chemistry or mathematics... then logical is that one does not think first of all about teaching, and when one gets there (refers to being a teacher), the first thing he does is, when one is a novice when one is new, the first thing he says is: *what I understood is what I am going to give to the student* , why? Because I understood that. *Q9:* So when we got to that point that we are newbies, because we care about covering content [...] I made a reflection many years ago when I had been teaching for five years, ten, fifteen, twenty ... and right now at thirty-two years old, because I already turn around and say: alas! many things have happened, because then I now distinguish what are the problems that a student always faces in the class, and when he is wrong, ahhh, it is that you were wrong in this ... and how did he know?, because experience tells us, and we can predict, even the article named him ... So, are the graphs important? yes, that we must position the student in a context, in a schematic map?	P5 motivated by the introductory reading for session two, reflects on the non-existence of training programs for Physics teachers in Mexico, (one of the elements we consider in this research), also reflects on the shallowness of some disciplinary knowledge that the Physics teacher should have, especially when he is a novice, which leads him to teach what he thinks he understood well in his professional training. P9 for its part makes a deep reflection on how its teaching practice has changed over time and is aware that it can now identify the difficulties that its students may have in different topics.
Session 2 Focus Group: Knowing Physics is necessary, but not enough to teach it.	*P7:* The science that we are going to impart, to know it very well, then I said that it was also important, not only to know it, but that we must have additional knowledge of other sciences that need to be integrated so that we can ehhh, rather than transmit, because it also criticizes the fact of transmitting knowledge because it already ... consolidated, already finished, finished [...] and another fact that I found interesting was that it talks about the importance of historical data, how such knowledge was generated, because finally the knowledge was generated experimentally and then not with particle accelerators, but for example with an inclined plane, how with simple experiments to which they could have access [...] *P3:* I consider that the more you study [inaudible] at least it is my case, that I do not know anything, I did not know anything, I have to enrich all this [...]	Motivated by one of the readings to start session two, P7 reflects on the need for greater disciplinary knowledge not only of Physics, in addition to the importance of incorporating the history of Physics and how the knowledge that he now teaches was generated. For its part, P3 also makes a deep reflection on the need for greater disciplinary knowledge.

Table 5. Indications of Learning by Inquiry.

The Physics Teacher Also Learns by Inquiry.	Transcript Excerpt	Comment
Session 3: Focus Group According to some precepts of the theoretical construct of *Teaching Physics by Inquiry*, the physics teacher must be instructed in a manner analogous to that which he should instruct his students. PCK Dimension: Knowledge and beliefs about the use of didactic resources and strategies to teach a particular topic of Physics.	*Instructor:[...]* Notice yesterday we took for granted that when an object moves in an inclined plane like the video they analyzed, we took for granted that it carries a constant acceleration, in fact I dared to say, we know that acceleration is constant because it is a component of the acceleration of gravity, and that's when I told you, even there we can try to estimate the acceleration of gravity, because we have the acceleration of the cart when it goes up and down the ramp, and then by the sine of the angle, and there the angle is giving us the same analysis of the video, then if we say that an object moving in an inclined plane has constant acceleration, it's because the acceleration in free fall is constant, the lowercase "g", isn't it? and we even know its value of 9.8... OKAY, when you say that to your students... how do you convince a student that a lowercase "g" is constant and worth 9.8? Or do they just tell them, and the students passively accept it? *P11:* Won't it be the same because they were told since high school? You know what? The value of "g" is 9.8; if we see it as something new, they tell us, hey, it's not 9.8? *P2:* What I do believe is students asking the questions, well and why? It's precisely the students who kind of have this profile to study science, and that's precisely where you should say, well, if you practice mathematics, you have a model where you can get that, right? but in the end, experimentation will give you value, always Physics, and in the experimental sciences, you have to go to the laboratory to measure that value. *P11:* It happens like when they are doing their projects, and the first time they don't work, and then they do another experiment, and I tell them, well, what failed them? Reflect on what is failing you, and then they begin to see and begin to formulate... Of course, they don't write hypothesis one, or hypothesis two, but they do create their hypotheses, right? And they are checking, having, if I change the voltage, if I increase it here, how these variable changes, that is an experimental phase, and they get their project to work. *Instructor*: Yes, one of the things that usually happen is that, if in the class we are going first to explain the theory, this, all the calculations can come out, but the student just as he says he wants to do an experiment or a prototype is when he says, listen to a teacher, but not that with this I calculated the angle?, and look, I put the angle, and it doesn't come out... Hey teacher, wasn't he going to calculate how far he would fall? And look, it falls less far [...]	Teachers begin to be questioned about how they convince their students that the value of the acceleration of Earth's gravity is the theoretical value that is used as data in many problems. Teachers accept that value is accepted by imposition because they do not remember measuring it experimentally themselves, nor do they usually do so with their students. In this case, the instructor proposes an emergent activity that he had not scheduled in the course to estimate the value of "g" using video analysis.

Table 6. Indications About the Teacher's Reflection of His Own Practice.

Reflection on the Teaching Practice Itself.	Transcript Excerpt	Comment
Session 1: Focus group: On the importance of the use of digital resources and the lack of preparation of teachers in this regard. PCK Dimension: Knowledge and beliefs about the use of didactic resources and strategies to teach a particular topic of Physics.	*Instructor:* What does it take to be a good physics teacher? *P4:* I would say that it must also be flexible... for example, right now, in terms of working with a computer, because many of us are dedicated only to whiteboards and do not get to do anything else, you have to use PowerPoint presentations, some program (software) in particular. *Instructor*: How can I improve my teaching practice? *P8*: Changing the strategies that are used because each time the technology advances, they are not the same as before the current ones. *P5*: Sometimes there is no need to change, but there is a need to adapt; that is indisputable. *P15*:[...] we already know that a methodology worked for me with a group, from which I observed that they learned, but maybe the next semester comes a group that brings a little more knowledge of technology, of advances. Maybe there someone says *teacher I know that there is this, could we use it?* *Instructor*: You have incorporated new didactic resources into your classes... what resources have you incorporated? *P8*: The platform, because at first, I did not use it because in the school where I worked, I did not have much technology, and later, I was able to use the platform to be able to send information to the students, videos, problems and activities. *P3*: The video tutorials, the simulators, the software... for electricity the simulators are very good... and there are several, many, also the platform and take advantage of the tools that are on the internet, on YouTube we have videos of the university recorded by the teachers themselves that if the boy can see it previously or can see it after his class if he did not understand him and the boy advances much better. *P5*: Well, what is incorporation, I would say, from the blackboards, right? As you say, 20 years ago, they were the traditional green ones, and if we come from there to date, there are many (resources). I also share what the teacher said because now there are many (teachers) who just want to use technology, and if there is no light they no longer want to teach.	Reflect on the different resources that are suitable for teaching Physics. However, some teachers only consider that technological resources serve to make their work more efficient (not having to dictate exercises, being able to send problems through a platform etc.), while it is clearly noted that Professor P5 is not so much in favor of the use of digital technologies.
Session 2 focus group: PCK Dimension: Knowledge and beliefs about the Physics curriculum. Knowledge and beliefs about the most effective ways to evaluate a specific topic of Physics.	*P3:* Sorry to interrupt you in that regard... a teacher told me how he could do a practice if he hadn't seen the theory... and it works for me the other way around, first the practice and then the theory ... *Instructor:* How interesting isn't it?, that as a question right?, I'm not saying that I have an absolute answer or that maybe it's wrong, but the question would be theory or practice first? And yes, it is very common to consider that the laboratory serves to test the theory... *P3:* That's what I said [refers to the professor in your comment] first, give me the equation, and since I have it, we go to the laboratory to check that it's okay... but it must have been the other way around... *Instructor:* In the very specific case of the topic that we are dealing with here, which is the interpretation of kinematic graphics because... maybe it doesn't seem like it to you, but even part of what we're seeing, if necessary, maybe it could be implemented as some kind of practice, the practice of interpreting graphics, and we're obviously using technology and resources, which maybe not everyone has, but it's easier to have free licensed software and a computer than maybe sensors and that kind of thing, then maybe if you had considered that kinematic graphics do not have to be done practical, or you cannot do, or there is nothing experimental there, well... maybe [...] *P3:* In my experience, I do have to see graphs because the guys who participate in the Olympics, in the experimental phase, which was just a short time ago... if they do not know how to build a graph, they are lost, at this stage it is very important. *Instructor:* And since you mention it, probably the first approach to graphics in Physics, precisely in mechanics with the kinematic motion graphics right? and later on may appear maybe another type of graphics right? as well as we are graphing in these sessions position against time, or speed against time, well later maybe what interests me is to graph force against time, or maybe there if I'm not going to graph it, but maybe given a graph of force against time, interpret it, right? knowing how to interpret graphics, it seems that we are convinced that it is fundamental, and in Physics because the first course that is given is mechanics, and that is the starting point for that. *P11*: [...] there must be more experimentation and complement it with theory and not pure experimental. It must bring that balance between theory and practice, the experimental.	Derived from the initial discussions prior to each learning task and motivated by the readings, P3 makes a deep reflection that evidences a declarative PCK in development, in this case it is questioned about the order of approaching the learning activities in Physics: first the theory or first the practice?He recognizes for the first time in the group the importance of the topic of kinematic graphics giving arguments. For his part, P11 is also reflective, and this seems to have a favorable impact on his declarative PCK, even though he has little teaching experience.

After reviewing the transcripts and the analysis presented in Tables 2 to 6, it can be considered that the dimensions of the PCK that were identified and chosen to design the instrument that allows characterizing this construct or were also useful for the design of the activities of the training course and that, to a greater or lesser extent, the proposed activities managed to influence one or more of the five dimensions of the PCK of the teachers who participated.

At the end of the training course, teachers were asked to answer the GC-PCK Test. During the development of the updating course the teachers who had the greatest participation were P2 (Bachelor of Physics), P3 (Bachelor of Chemistry), P9 (Industrial Engineer), and P11 (Industrial Engineer); the difference between the years of experience are considerable, while P3 and P9 have more than 20 years teaching Physics in high school, P2 and P11 are less than 5 years old (see Table 1 for more information). Additionally, it was decided to consider for the analysis the scores of teachers P1 and P8 because both had less participation, however, it is relevant to contrast that while P1 has only 4 years of experience as a Physics teacher, P8 has 9 years of experience.

For this reason, it was considered pertinent to specifically review the score obtained in the test by these participants.

Below is a summary of the scores obtained by these teachers on the test:

Table 7. Test Score of Some Course Participants.

Participant	Test score (out of a total of 112 points)
P1	79
P2	85
P3	77
P8	71
P9	77
P11	67

The results presented in Table 7, suggest that initial training may be a more influential factor than teaching experience in the PCK declarative of a specific topic. In this case, P2 is a teacher who, although has little teaching experience, is the only teacher who has as initial training the degree in Physics; it also suggests that the teaching experience can favorably influence the declarative PCK. P3 and P9 are the teachers with the most teaching experience, while P11 despite being active and reflective during the process, has little teaching experience.

4. Discussion

In practical terms, it would be unlikely to think of training programs that included courses in which each of the topics of the Physics curriculum was addressed. In the case of this study, the topic of kinematic graphics turned out to be plausible since it is content that recurrently appears in the syllabuses and textbooks of the mechanics' courses for high school. The analysis of kinematic graphics can connect with topics that appear later in the mechanics' study program, for example, with energy conservation or collisions in one and two dimensions. The suggestion for those who intend to follow the methodology set forth in this paper is to identify central topics of the syllabus, in which most other topics could converge so that consequently, courses such as the one presented here could be designed based on the PCK's characterization of physics teachers for those specific topics.

Specifically, the main findings obtained in the qualitative stage of this research work (design and delivery of a training course) are the following:

A) The Use of Digital Tools Helped to Modify the Pck

- The designed learning activities managed to influence some of the dimensions of the teachers' declarative PCK, which was evident in some transcription fragments presented in Table 3, for example, dialogue motivated by task 7 of session 4. Similarly, the professors reflected on dimension 3 of the PCK: "Knowledge and beliefs about the preconceptions and previous ideas that students have in a specific topic of Physics" by contrasting their own preconceptions and then being able to discard those that are erroneous when developing the activity. Likewise, the activity has an impact on dimension 4 of the PCK "Knowledge and beliefs about the use of didactic resources and strategies to teach a particular topic of Physics," since the teachers declared at the beginning of the course that most of the resources they use in their classes are PowerPoint presentations. , and with the activity, they have a different approach to a resource that allows them to address the same curriculum topics that they usually address with different resources.
- The resources chosen (GeoGebra and Tracker) to develop the activities of the course had a favorable impact on some of the dimensions of the PCK, as can be seen in the transcription fragments rescued in Table 8, dialogue that was developed when working with Activity 4 of session 2. It can be observed that the use of the didactic resource Tracker, has an impact on dimension 2 of the PCK "Knowledge and beliefs about the difficulties of teaching a specific topic of Physics", by allowing the teacher to reflect on the possible answers that the student would give if he developed the activity.
- Starting each activity with some element that contextualizes is favorable to motivate reflection, it was sought when designing the tasks, that each one had a contextual element of the beginning, and in the case of Activity 7 of session 4, propitiating it with a video of a cartoon (coyote and road runner), led teachers to reflect on the principle of inertia and the way in which physical thinking was developed in as for movement phenomena, as can be seen in the fragment recovered from Table 3.
- As another outstanding finding, the design of the activities and the use of the proposed digital resources, favored episodes compatible with the construct "Learning of Physics by Inquiry", and also favored the teaching of Physics as an experimental science, as can be seen in some transcription fragments collected in Table 5, in this case, a fragment of activity 1 of the first session, developed with GeoGebra.

B) Implementing Episodes of Reflection on Their Teaching Practice for Continuous Improvement is Important.

- The reflection on the teaching practice itself, motivated by different readings that were provided to the teachers, or questions that were asked in plenary, is also an element that can affect the PCK of the teachers, as can be seen in the transcription fragments compiled in Table 6.
- It was also possible to verify that some teachers may have disciplinary difficulties analogous to those that students may have, although, without the application of an instrument that measures disciplinary knowledge in the topic of kinematic graphics, such as the TUG-K Test, it cannot be assured, however, indications were found, such as those mentioned by [44], which has to do with the fact of not taking for granted that Physics teachers have deep disciplinary knowledge in each topic of the same, which can be seen in Table 4, for example, in session 4 during the activity as a focus group.

5. Conclusions

In conclusion, our study demonstrated that establishing courses that cover each of the subjects taught in the Physics curriculum is unfeasible. It has also been demonstrated that emphasizing in significant concepts with connections to other parts of the curriculum can be useful in boosting teachers' Pedagogical Content Knowledge (PCK) for those particular subjects. The integration of digital tools such as GeoGebra and Tracker has been proved to be beneficial in changing instructors' declarative PCK dimensions. Additionally, incorporating assessment sessions about their educational approach is critical for continuing enhancement. Teachers can detect and rectify their own prejudices and misconceptions through the use of didactic instruments and strategies that they may not have considered previously. Finally, this study revealed the significance of teaching Physics as a field of experimentation and employing inquiry-based learning methodologies. Overall, this study has provided useful insights for improving physics education in high schools.

Several areas for further research could be identified based on the findings of this study. First, a follow-up study to assess the long-term influence of the training program on instructors' pedagogical topic understanding and classroom practices would be compelling. This could aid in determining if the improvements reported in this study were sustained over time and had a favorable impact on student learning outcomes. Second, subsequent studies could inquire into the efficacy of the training program for teachers of other science courses, such as chemistry or biology. This could help determine whether the approach used in this study could be applied to other science disciplines and result in similar gains in instructors' pedagogical content understanding. Third, it would be useful to assess the influence of the training program on student learning outcomes. This could entail comparing the performance of kids whose instructors took part in the training program against that of students whose teachers did not, to determine if the program had a beneficial effect on the achievement of students. Finally, future research should evaluate the usage of various digital tools and resources for teaching Physics, as well as their impact on instructors' pedagogical content understanding and classroom practices. This could aid in the discovery of new and novel ways of teaching Physics that are far better than standard methods.

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