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YOUTUBE VIDEOS ON THE PYTHAGOREAN THEOREM:
Didactic Analysis of the Relevance of Audiovisual Content

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ABSTRACT

This article presents the findings of a research study that set out to carry out a didactic analysis of the relevance of audiovisual content of YouTube videos on the Pythagorean theorem in accordance with the guidelines of current didactic theories. In the mixed-methods study, a descriptive analysis was employed for quantitative data and a discourse analysis for qualitative data. In general, the videos in question fail to demonstrate the use of conceptual elements (point, line and plane), visual elements (colour, size, texture, contrast) and relational elements in relation to space. Furthermore, the use of formal language is inadequate, with a lack of contextualised applications and cases, sources and resources for learning, and feedback. This contrasts with the attention paid to previous knowledge. The videos analysed do not present relevant audiovisual content.

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1. Introduction

The advent of the information society has given rise to a plethora of alternative avenues for learning, prompting educational stakeholders to seek supplementary resources to enhance their training activities and achieve the objectives of formal learning. Social networks, which have gained immense popularity among the general public, are among the most frequently utilised platforms by young people for a diverse range of purposes, including communication and information-seeking for both educational and recreational purposes (López-de-Ayala et al., 2020). With regard to networks, Gupta & Bashir (2018) have identified their use in socialisation, information, entertainment and education. Pires et al. (2021) have identified the following uses for YouTube: Radio, television, social, productive and educational. With regard to social networks in education, different studies indicate that it is possible to establish learning environments that overcome space-time barriers (Fonseca-Peso et al., 2020). This configuration allows for the use of information at any time of life and the combination of information from different channels (Ramires-Lima et al., 2020). This generates didactic innovation through peripheral and emergent interactions (Greenhow & Chapman, 2020).

Social networks, such as YouTube, facilitate the dissemination of videos that are consulted by students from a range of educational levels and subject areas, engaging multiple senses to enhance learning outcomes. However, these represent a minor proportion of the total content, which is primarily focused on entertainment (McGrady et al., 2023). The theory of multimodal learning posits that the integration of modes of representation, such as text, image and sound, can enhance comprehension and retention of information (Mayer, 2020). Moreover, this theory is predicated on the assumption that the brain processes information more efficiently when it employs multiple sensory channels simultaneously, as is the case with videos.

Vera and Moreno (2021) identified YouTube as an alternative learning site, indicating a need for its integration into formal education. Prior evaluation of the content of videos disseminated on this network is recommended. In their study to "discover the evaluations of the characteristics of YouTube as an informal learning medium", Colás-Bravo & Quintero-Rodríguez (2022) identified two key aspects. Firstly, respondents emphasised the instrumental aspects of YouTube, including "the rapid acquisition of knowledge and the flexibility to learn at a time and place that suits them". Secondly, they highlighted the pedagogical benefits of the platform, including "its use of mobile devices as learning mediators (mlearning), the ability to personalise learning through instructor choice and explore diverse learning formats". The advent of new technologies has precipitated a revolution in didactic action, with the establishment of learning environments, transposition of learned knowledge into practice and access to vast quantities of information playing a pivotal role (Martínez-Domingo et al., 2021; Al-Ahmad; Obeidallah, 2019).

In the present era, social networks have become invaluable learning resources. Since 2020, YouTube has been identified as an innovative didactic option (Martínez-Domingo et al., 2021). The use of YouTube videos as a tool for informal learning has become increasingly prevalent (Colás-Bravo & Quintero-Rodríguez, 2022), with the aim of enhancing classroom learning. However, it remains unclear whether the audiovisual content of YouTube videos is relevant to students. As Monroy (2024) notes, "the utilisation of such resources must be meticulously planned and evaluated in order to guarantee their efficacy within the teaching and learning process" (p. 126). In order to respond to the aforementioned question in the context of mathematics, the study sought to examine the relevance of the audiovisual content of YouTube videos designed for the purpose of learning the Pythagorean theorem.

1.1. Theoretical framework

The concept of relevance is of paramount importance in the selection of information, as it determines the extent to which the chosen data aligns with the specific needs of the individual or organisation in question. This quality is not intrinsic to the information itself; rather, it is contingent upon its relevance to the information demands of the user. Criteria have been established for the analysis of the structural, thematic, methodological and communicative aspects of audiovisual content in online videos.

A) The structure of the videos

The utilisation of videos represents a fundamental element that enhances the efficacy of the didactic process (Guijosa, 2018). A clear and coherent structural design facilitates the organisation and logical sequence of information, which is crucial to promote comprehension and retention of content. Mayer et al. (2020) posit that the structure of a video should facilitate the segmentation of information into

discrete, coherent units that facilitate effective processing and assimilation of knowledge by the learner. The structure should permit intuitive navigation through the content, thereby facilitating review and revision of specific concepts when necessary. Furthermore, the structuring of multimedia elements should be considered in order to facilitate their integration and avoid cognitive overload (Moreno & Mayer, 2007). This entails the utilisation of graphics, text and animations in an arrangement that adheres to the principle of spatial and temporal contiguity, whereby associated information should be presented in close proximity, both in space and time, to optimise comprehension of the content (Domínguez et al., 2018).

The aesthetic quality of graphics and animations in educational videos is of vital importance in capturing students' attention and facilitating comprehension of complex concepts. Therefore, the designs must be visually appealing and didactically functional. Liu and Elms (2019) posit that the aesthetic quality of graphics and animations can optimise learning outcomes by increasing interest, improving comprehension, facilitating flexible learning at every pace and providing a choice over conventional teaching materials. The key aspects of aesthetic quality are clarity and accuracy in the visual representation of concepts (Mayer et al., 2020). Furthermore, the technical quality of the videos, including the clarity of the images and audio, is of paramount importance to prevent distractions and ensure that the learner can focus on the learning content without interruption. As Yang et al. (2022) conclude, high video clarity is more advantageous for learning, whereas low video clarity is conducive to the visual occlusion effect (VOE), which significantly affects learning efficiency (p. 201). Furthermore, Kurniawan et al. (2022) posit that good visual design in videos contributes significantly to creating a more effective and enjoyable learning experience. It is essential that visual elements are designed in a way that guides attention to the core content and facilitates meaningful connections between concepts. This approach will help to prevent learners from disengaging from the video at an early stage.

It is crucial to understand the relationship between texts and geometric figures in order to gain a deeper comprehension of the subject matter. It is essential that texts complement and elucidate the geometric figures, providing a verbal context that facilitates the interpretation and comprehension of the visual representations. Eye-tracking studies (Persson et al., 2019) have demonstrated that viewers devote a considerable amount of time to the captions and written text of videos before directing their attention to the graphic. This underscores the significance of synchronising the visual and verbal elements effectively for optimal learning, which is a crucial aspect in grasping mathematical concepts. Makhlouf and Iñigo (2022) conclude that the image "must be congruent in its textual, visual, and auditory content, ensuring that the product has unity of meaning and is clear and precise for a specific reader or viewer". (p. 18)

The readability and layout of text in videos are critical factors affecting the accessibility and comprehensibility of information. Lange & Costley (2020) posit that issues with "text size may manifest when the font size is insufficient, thereby rendering text presented in an instructional context illegible and, subsequently, affecting comprehension levels" (p. 4). An appropriate layout facilitates reading and assists in the processing of information, enabling the reader to focus on the key ideas. As Makhlouf & Iñigo (2022) observe, in the creation of audiovisual materials, "the manner in which the material is presented, the movement of the images, their transitions and the sequence in which they are presented influence the way it is received" (p. 5). As Hidayah (2023) notes, the use of colours and images in videos can facilitate the imagination of abstract concepts. Another tool that can be employed to clarify the message is signposting. This directs attention to specific elements, which can serve to reduce superfluous cognitive load by enabling the learner to identify which elements are important. It can also serve to increase relevant cognitive load by emphasising the organisation and connections in the information presented (Brame, 2016).

B) Thematic content in the videos

The quality of video content is a significant determinant of its efficacy in facilitating learning, particularly in the context of mathematics, where conceptual understanding and application are paramount. It is therefore essential that information is presented in a clear and accurate manner, facilitating understanding and application of the material in different contexts. Excessive information should be avoided, with the focus being on the key concepts. Luby and Southern (2022) posit that clarity and conciseness in the communication of academic subjects is essential to enhance comprehension, interest and engagement. Mayer (2021) has also demonstrated that: "The use of personalised language is intended to facilitate a sense of individualisation between the instructor and the learner, which can engender a greater sense of motivation to exert the necessary effort in order to comprehend the

information being conveyed" (p. 243). Mayer (2021) designated this principle the "personalisation principle". The importance of creating concise educational videos has been emphasised by numerous studies. Pattier (2022) notes that YouTube users typically seek immediate solutions to their queries, particularly in mathematics, and favour videos that are concise, free from extraneous elements, and provide optimal explanations.

The utilisation of prior knowledge is a fundamental aspect of facilitating the comprehension of novel concepts, as it enables students to establish connections between new information and their existing knowledge base (Ausubel, 1978). Educational videos should be designed in a way that builds on students' existing knowledge, providing a context that facilitates the integration of new information and its application in different situations. Li (2018) discovered that students with considerable prior knowledge were more likely to employ visualisation techniques to enhance their comprehension of the subject matter. This approach is based on constructivist learning theory, which posits that students learn best when they can connect new information with prior knowledge. The utilisation of concepts and direct experiences facilitates the establishment of connections that enhance students' comprehension and retention of information.

It is of the utmost importance that mathematical syntax is accurate in order to facilitate learning of mathematical topics. It is imperative that videos present theorems, algorithms and concepts in precise and correct mathematical language, avoiding any errors that may lead to confusion. The correct use of mathematical syntax encompasses the utilisation of accurate notation and the elucidation of formulas, equations, and other mathematical constructs. The significance of this is elucidated by Kulgemeyer & Wittwer (2023), who have demonstrated that students who engage with explanatory videos that present erroneous concepts may develop a misperception of comprehension. Contextualised content is also fundamental to the reinforcement of learning and the facilitation of knowledge transfer.

C) Communication in videos

Effective communication through the medium of educational videos is an essential component of ensuring that students are able to comprehend and retain the information presented. In the field of mathematics education, it is of paramount importance that videos convey concepts in a clear and accurate manner, utilising a combination of text, symbols, figures and an appropriate logical sequencing of content. An effective explanation in videos is based on the use of texts, signs and figures that facilitate the understanding of concepts. Mayer (2020) posits that learning is significantly enhanced if visual and textual elements are properly combined, as this allows the learner to process information more completely and effectively. This is because combining elements helps to represent abstract concepts in a concrete way, in accordance with his "multimedia principle".

The utilisation of symbols and graphics is pivotal in facilitating the acquisition of mathematical knowledge through video-based learning materials. It is, therefore, imperative that these visual aids are presented in a coherent and unambiguous manner, thereby ensuring that the learner is able to comprehend the subject matter and apply it in a variety of contexts. The introduction and explanation of symbols should be conducted in a manner that ensures the student's comprehension of their function and their relationship to other concepts. Furthermore, it is crucial that the graphics utilized in video presentations are accurate and well-designed to prevent confusion. They should be aligned with the accompanying text and other visual elements to ensure a coherent representation of the information being conveyed. For instance, the utilisation of dynamic graphics can facilitate comprehension of mathematical topics, such as the Pythagorean theorem, by enabling students to manipulate and explore the concepts visually. In their 2022 study, Silva and colleagues conclude that the visual language employed in videos can facilitate the systematic organisation of knowledge and enhance the visualisation of mathematical content. (p. 14)

Puga et al. (2016) posit that "mathematical language allows interrelating formal and abstract language with natural language, through principles and rules that are briefly described" (p. 207). This assertion implies that the relationship between mathematical language and common language facilitates the understanding of complex concepts, connecting formal language with everyday facts and terms. This connection enables learners to perceive the applicability of mathematical topics in everyday life and to comprehend how they can be deployed in diverse contexts. This is particularly crucial for students who may experience challenges with formal language or who may be daunted by the intricacy of mathematical concepts. In relation to the issue of student disaffection with mathematics, Puga et al. (2016) posit that this challenge "can be addressed through the utilisation of pedagogical resources that prioritise the acquisition of authentic and contextualised learning" (p. 207). The sequence of the video

should be clear and logical, facilitating the progressive understanding of the subject. It should be designed in such a way that each new concept is based on previous knowledge (Ausubel, 1978) and that the progression of the information is easy to follow. The introduction of basic concepts should precede the introduction of more complex topics, and the review of key concepts should follow the introduction of new information. This approach allows for the reinforcement of learning and optimisation of understanding and assimilation of new information.

D) Methodology in the videos

The utilisation of video methodology should facilitate active and meaningful learning. It is essential that visual and sound effects capture and hold the attention of the learner. The incorporation of visual elements, such as dynamic graphics and animations, in conjunction with sound effects that reinforce the information presented, has the potential to enhance the learning experience by facilitating the comprehension of complex concepts. This is evidenced by the assertion that "animated videos are not only beneficial in improving students' knowledge of mathematical topics but are also fun and effective in improving mathematical problem solving" (Nasution & Lailia, 2023, p. 1353). It is recommended that videos include elements designed to arouse curiosity and interest, as well as applications that demonstrate how mathematical topics can be used in real-life situations. This facilitates the transfer of knowledge and increases student motivation for the usefulness of what is learned, provided that the language used is tailored to the individual (Mayer, 2021).

It is of the utmost importance to encourage interactivity in the learning process, as it enables the student to play an active role in the didactic process. Incorporating interactive questions, exercises and activities into the videos is an effective method to foster reflection and the application of learned concepts, thereby maintaining interest and enhancing comprehension and retention of the information. Consequently, videos may incorporate questions and answers, thereby enabling students to assess their comprehension and obtain the requisite feedback (Espinoza, 2021). Furthermore, supplementary educational materials are essential for reinforcing comprehension and providing learners with opportunities to investigate and grasp the subject matter. It is recommended that videos be accompanied by supplementary materials, such as interactive exercises and additional readings, which enhance the learning experience. Such resources should be designed with the objective of fostering autonomy in learning, thereby enabling learners to engage in self-paced exploration and comprehension of the subject matter. The didactic sequence is of paramount importance, as it creates the conditions for meaningful learning (Cristaldo, 2023). In accordance with the cognitive theory of multimedia learning, Mayer (2014) posits that videos facilitate the selection of pertinent words from the text and relevant images from the graphics displayed. Additionally, they enable the organisation of these chosen words and images into a coherent representation, as well as the integration of graphic and verbal representations with existing knowledge (Ausubel, 1978). Consequently, the design of the video is of paramount importance. Godino et al. (2007) present a set of criteria for the suitability of audiovisual resources in the context of the didactic process, encompassing epistemic, cognitive, interactional, media/resources, emotional and ecological dimensions. Romero et al. (2017) establish a set of criteria for the selection of videos, which serve as a reference for their production, including curricular, technical, aesthetic and expressive, didactic and accessibility considerations.

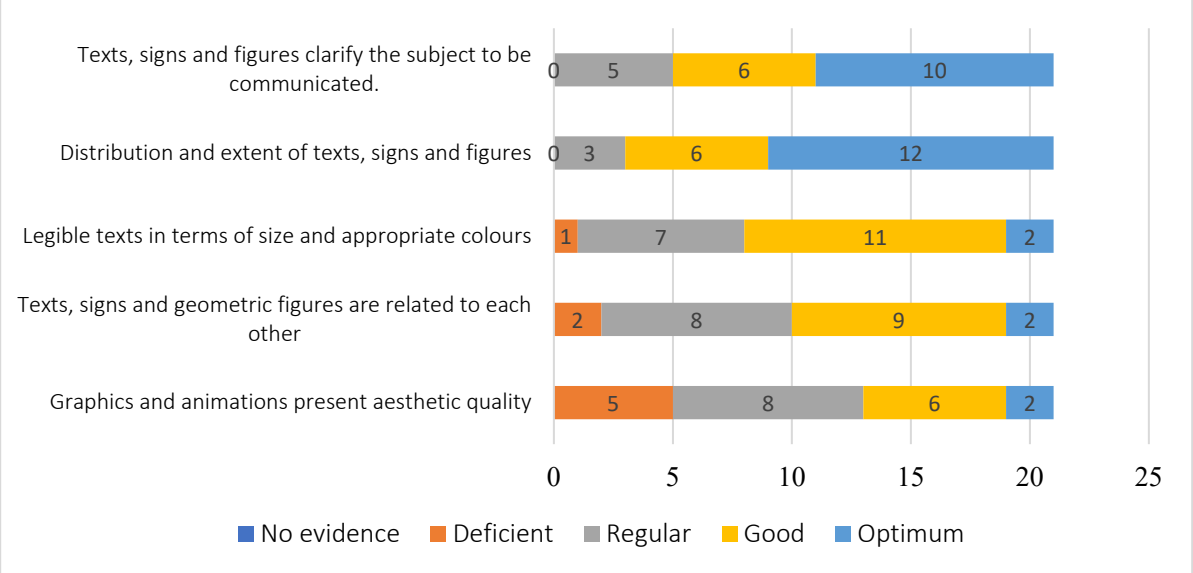
2. Methodology

The study employed a mixed-methods approach to data collection and analysis. The theoretical framework is contextualised in order to address issues related to the development of an ad hoc file that seeks to obtain both quantitative and qualitative data from the videos selected on YouTube for the respective analysis. Discriminative sampling, in conjunction with selective coding, was employed to ascertain the inter-relationships between categories. A total of 21 videos were viewed, following the attainment of saturation (Martínez-Salgado, 2012; Ortega, 2020). The sample of videos was selected in accordance with the following inclusion criteria: the presence of sound, broadcast in Spanish between 2017 and 2024, and a duration of between four and 12 minutes. The videos were not differentiated based on their geographical origin, educational level, age, or the gender of the YouTuber. The quantitative data obtained from viewing the videos was subjected to descriptive analysis, while the qualitative data, derived from translating the spoken discourse of the videos into texts in Word, underwent discourse analysis.

3. Results and discussion

The following section presents the findings of the data processing undertaken with regard to the structure, thematic content, communication and methodology of the videos.

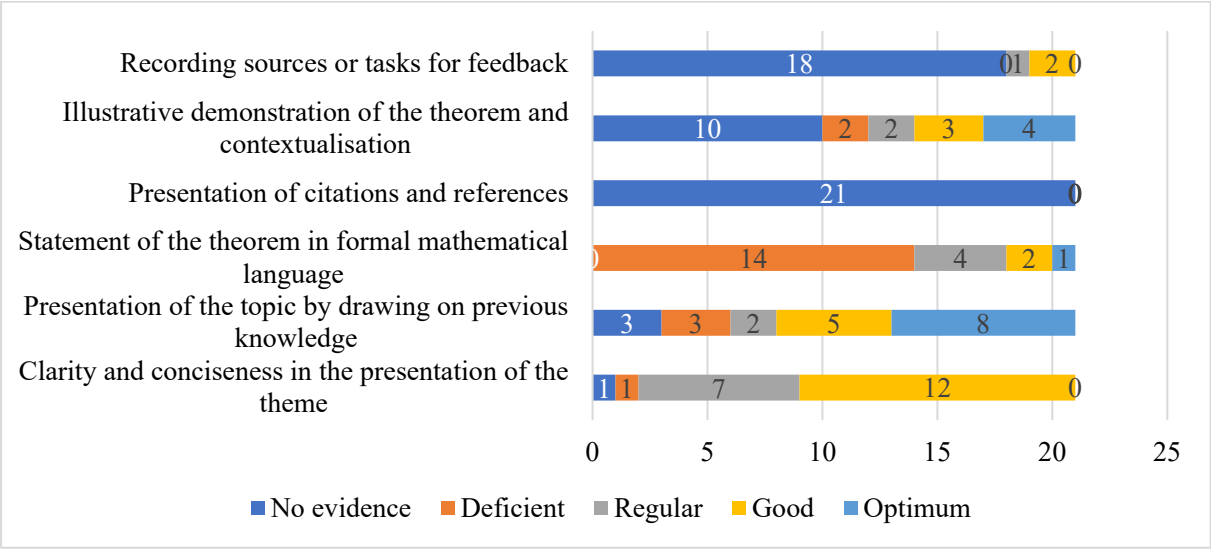
Figure 1. Structure of YouTube videos on the Pythagorean theorem.



Source. Own elaboration, 2024

The YouTube videos related to the Pythagorean Theorem, which are used as a support tool in informal learning, display a high frequency of graphics and animations. However, the structure of these videos is not uniform, ranging from poor to good. In contrast, the relationship between texts, signs and figures presents a regular or good structure. This assessment is also applied to the legibility of texts in terms of measures and colours, which contribute to learning (Guijosa, 2018). The highest frequencies in terms of the relationship between texts, signs and figures correspond to regular or good results, which improve with regard to the legibility of the texts in terms of appropriate size and colours, which correspond to good or optimal frequencies. In general, the videos displayed lack sufficient relevance in terms of structure. They fail to respond to curricular purposes and instead respond to the interest of those who design them, without technical criteria. Consequently, they do not make suitable use of conceptual (point, line and plane), visual (colour, size, texture, contrast) and relational elements in relation to space, which could optimise the design to improve learning. The limitations of video can result in an inadequate didactic transposition, which students can circumvent by requesting reliable videos on the subject from their instructors. It is important to note that technologies have significantly impacted didactic practices and are now integral to learning experiences (Martínez-Domingo et al.). (2021). The structural aspects of the videos render them a valuable educational resource, particularly in the context of learning the Pythagorean theorem.

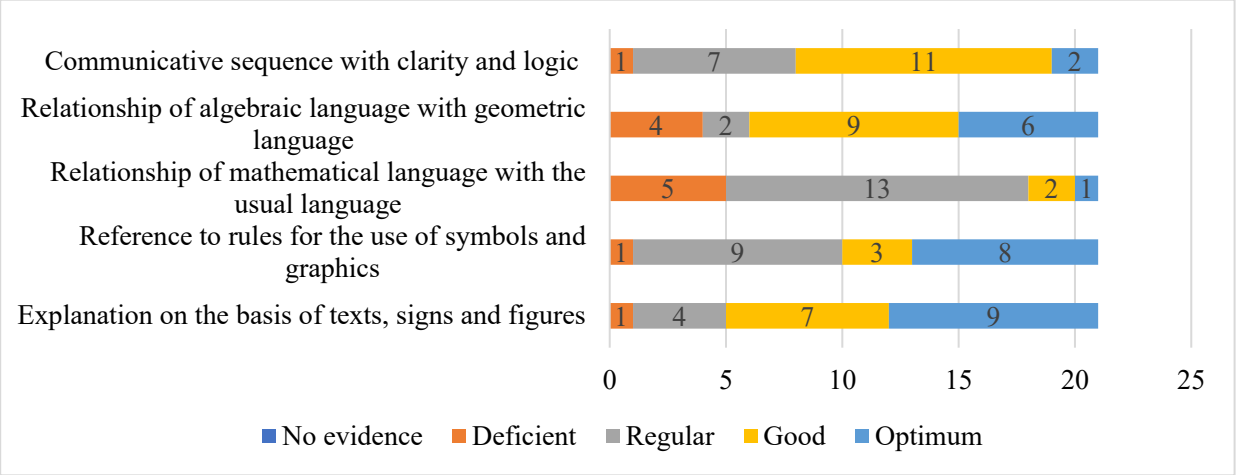
Figure 2. Thematic content in YouTube videos on the Pythagorean theorem.



Source. Own elaboration, 2024

While the videos predominantly demonstrate the Pythagorean theorem in a succinct and lucid manner, due to the illustrative elements and the integration of prior concepts (Ausubel, 1978), there is a dearth of precision in the articulation of the theorem, which is deficient in its utilisation of mathematical concepts. The theorem may be expressed in natural language, with or without the use of algebraic or geometric terminology. In the initial instance, the following is observed: "Given any right triangle whose sides measure a, b and c, where c is the side opposite the right angle, the Pythagorean theorem can be stated as follows: a2 + b2 = c2" (Strathern, 1999, p. 9). 9) The second relationship is expressed as follows: "In every right triangle, the length of its hypotenuse squared is equal to the sum of the squares of the lengths of its legs." This can also be stated in algebraic terms: "in every right triangle it is true that the sum of the squares of the lengths of its legs is equal to the square of the length of its hypotenuse." However, in natural and geometric language it can be stated as follows: "In every right triangle, the area of the region bounded by the square constructed on the hypotenuse is equal to the sum of the areas of the regions bounded by the squares constructed on the legs" (Barreto, 2010, p. 72). Alternatively stated: "In every right triangle, the area of the equilateral triangle constructed on the length of the hypotenuse is equal to the sum of the areas of the equilateral triangles constructed on the lengths of the legs" (Barreto, 2010, p. 72); more formally, the area of the region bounded by a triangle. However, in most videos the statement of the theorem is deficient, as it states the following: "In a right triangle, the square of the hypotenuse is equal to the sum of the squares of the legs." This is an inaccurate representation of the theorem, as the terms "square of the hypotenuse" (V2, V3, V16) and "squares of the legs" are erroneous expressions. This is because the hypotenuse and the legs are segments, and thus do not admit squaring, which is associated with a number. Furthermore, there is a lack of evidence regarding the extension of this theorem (López et al., 2018). This refers to other cases in which the sides of the triangle are not sides of three squares but of other polygons similar to each other or of any type of figure, also similar (Caballero and Castillo, 2023). These results contrast with the attention to prior knowledge, which is beneficial for the understanding of the subject (Li, 2018; Ausubel, 1978). There is no evidence of citations of the ideas presented or the respective sources, which detracts from the reliability of the presentation. The highest frequencies correspond to the non-contextualised presentation of the theorem, which has been identified as a disadvantage in learning (Puga et al., 2016). Furthermore, as the highest frequencies indicate, the absence of references or hyperlinks to sources results in the omission of feedback, which can negatively impact learning (Espinoza, 2021). The aforementioned aspects render the videos an inadequate resource for learning the Pythagorean theorem, as they lack relevance to the subject matter.

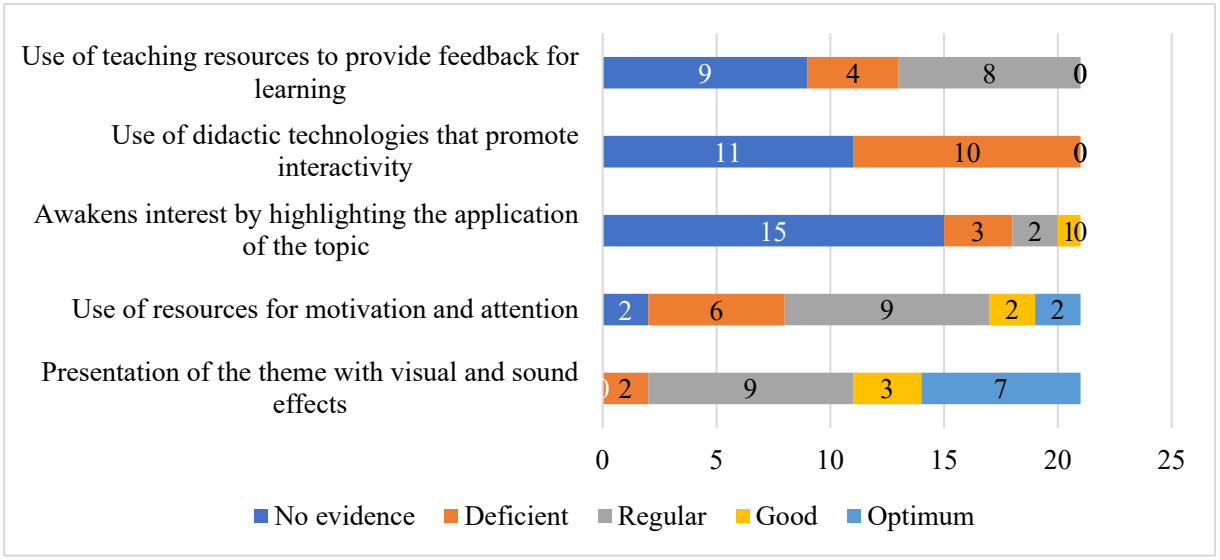
Figure 3. YouTube video communication on the Pythagorean theorem.



Source. Own elaboration, 2024

The strength of the videos on the Pythagorean theorem lies in their higher frequencies, which indicate optimal explanations based on texts, diagrams, or figures. This is advantageous for learning (Silva et al., 2022). However, the higher frequency of such videos only alludes to regular use of rules for the use of symbols and graphics. This is analogous to the relationship between formal language and natural language, which is also regular. This relationship does not have a favourable impact on learning (Puga et al., 2016). Similarly, the highest frequencies indicate a positive relationship between communication in geometric and algebraic languages. Furthermore, the highest frequencies demonstrate a coherent and logical didactic sequence, which is advantageous in line with the recommendations of Cristaldo (2023) and Luby and Southern (2022). The aforementioned characteristics render the videos a valuable resource for learning the Pythagorean theorem, particularly in terms of their communicative elements.

Figure 4. Methodology used in YouTube videos on the Pythagorean theorem.



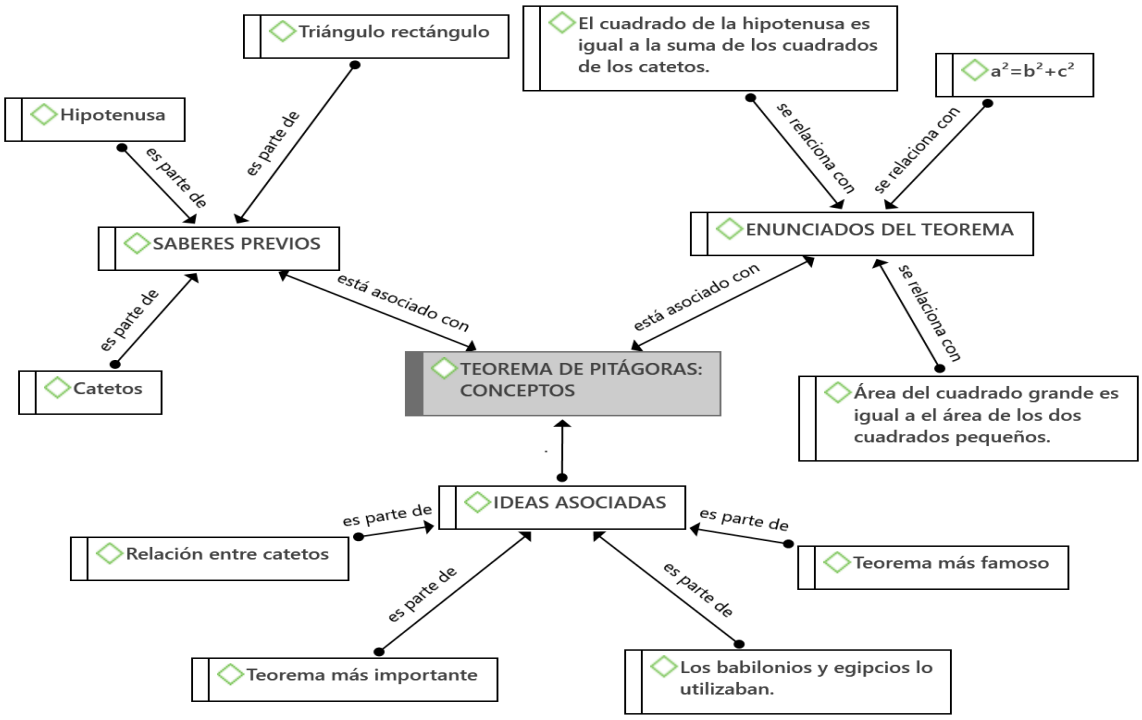
Source. Own elaboration, 2024

The methodology employed in YouTube videos on the Pythagorean theorem indicates that the highest frequencies correspond to regular or optimal presentations of the topic with visual and sound effects. However, in terms of motivation and attention, the highest frequencies only refer to poor or regular evaluations, which does not correspond to the findings of Mayer (2021). The highest frequencies indicate a lack of evidence or deficiencies in the application of the topic, encouragement of interactivity, and learning feedback. These factors do not contribute to the optimisation of mathematical knowledge construction (Nasution & Lailia, 2023) nor the selection of relevant words from the topic texts, as Mayer (2014) has indicated. These deficiencies render the videos an inadequate educational resource, as they lack an appropriate methodology that would facilitate optimal learning of the Pythagorean theorem.

The following section presents an analysis of the content of the transcripts of YouTube videos on the

Pythagorean theorem. In terms of prior knowledge, the theorem and associated ideas are presented. In addition, demonstrations and applications are discussed.

Figure 5. Concepts associated with the Pythagorean theorem in YouTube videos.



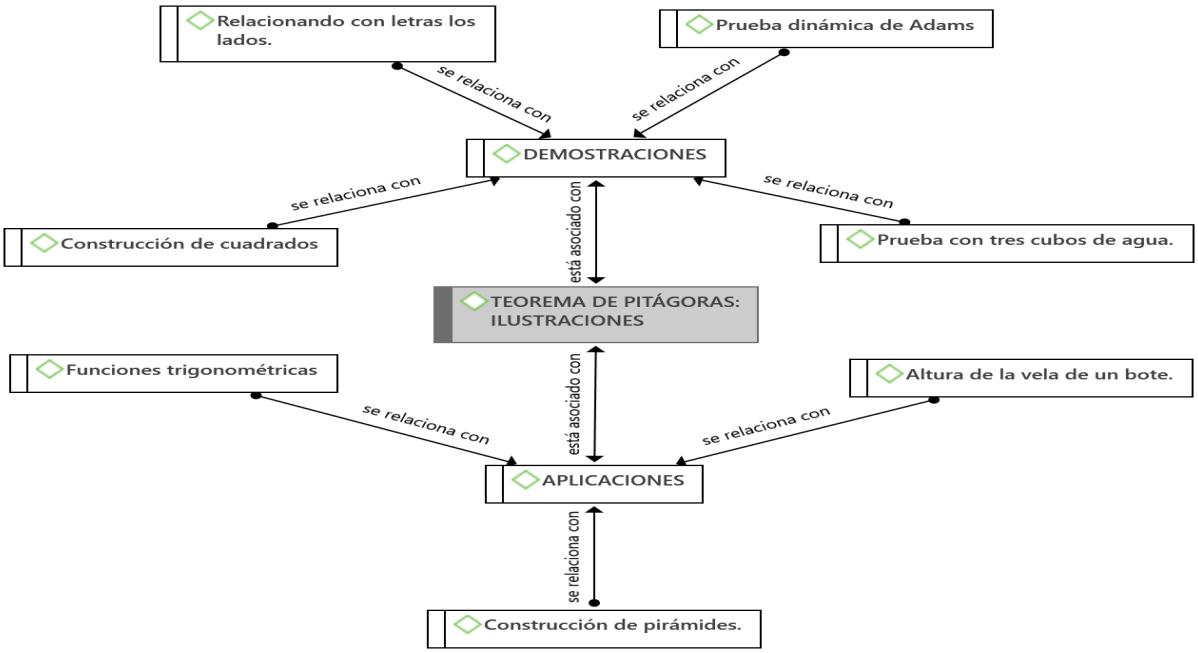
Source. Own elaboration, 2024

In the presentation of the Pythagorean theorem, the highest frequencies serve to highlight previous concepts, emphasising the right triangle and its constituent elements. This can be observed in a number of instances. A triangle is defined as right-angled when one of its interior angles is 90 degrees (Video 2-V2, V5, V15, V20). It is crucial to recognise a right-angled triangle, as the Pythagorean theorem is only valid for triangles of this type (V8, V14, V17). The hypotenuse is defined as the side opposite the right angle. The legs, designated as "A" and "B," form a right angle (V3, V6, V13). The Pythagorean theorem is applicable to all triangles containing a right angle (V5, V10, V16, V18). All of the aforementioned statements are accurate and pertinent.

The Pythagorean theorem is a concept that lends itself to a variety of presentations; "The Pythagorean theorem states that the square of the length of the hypotenuse is equal to the sum of the squares of the legs" (V7, V19); "The hypotenuse squared is equal to the sum of the legs squared" (V8, V16, V20); "In every right triangle, the sum of the squares of the legs is equal to the square of the hypotenuse" (V9). V18, V21); "The theorem states that the square of the hypotenuse is equal to the sum of the squares of the legs" (V10, V16, V19); "In a right triangle whose legs measure b and c and whose hypotenuse measures a, the square of the hypotenuse is equal to the sum of the squares of the legs" (V11, V18, V20). All of the aforementioned statements differ from those expressed in terms of the ratio of the lengths of the sides of the right triangle: "In a right triangle, the square of the hypotenuse is equal to the sum of the squares of the legs". This can be expressed in terms of the lengths of the sides using letters: "If the hypotenuse is a and the legs are b and c, then a2=b2+c2". However, there is no evidence of proper wording in mathematical language in the statement of the theorem.

The historical significance of the Pythagorean theorem is evident in the content of several videos on the subject. The Pythagorean theorem has a long history, with evidence of its use by ancient civilisations such as the Babylonians and Egyptians. Even the president of the United States, Garfield, demonstrated its applications (V3, V4, V17, V20); "The theorem is regarded as one of the most significant and well-known statements in mathematics. It has numerous applications in mathematical and everyday contexts" (V11, V15, V21). The content of the remaining videos is aligned with some of the aforementioned cases.

Figure 6. Concepts associated with the Pythagorean theorem in YouTube videos.



Source. Own elaboration, 2024

A review of the videos revealed that the Pythagorean theorem is not typically demonstrated in an illustrative manner. In some cases, illustrations are used to demonstrate the construction of squares on the sides of a right triangle, and the areas of the respective regions are related (V5, V21). In other instances, letters are employed to relate the sides of a right triangle (V8, V16, V18). Additionally, the demonstration presented by J. Adams is accompanied by animation (V9), and an "illustration with cubes" is provided (V10). In other cases, the theorem is verified with numbers. Applications are provided for "the construction of the pyramid of Chephren" (V11), "the calculation of the height of a sail on a boat" (V12), and "the trigonometric ratios of the measure of an alpha angle are the ratios obtained between the lengths of the three sides of a right triangle" (V3). The content of the remaining videos is consistent with the aforementioned cases. While some concrete applications are provided, there is a notable absence of contextualised mathematics, which is generally not sufficiently relevant in terms of communication and thematic content.

4. Conclusions

Videos constitute a valuable resource for students at all levels of education and in all modalities, serving as a valuable complement to their asynchronous learning experiences on specific topics, facilitating the provision of feedback. Such videos are disseminated on social networks, particularly YouTube, which is the most frequently consulted network. These widely used resources, designed for informal learning, fail to consider technical pedagogical requirements in terms of structure, content, communication and methodology. This is evident in the YouTube videos on the Pythagorean theorem, which fail to provide an appropriate didactic transposition and do not facilitate the desired learning outcomes.

The YouTube videos on the Pythagorean theorem, as support tools for informal learning, have been analysed and found to exhibit considerable variation in terms of the quality of their graphics and animations. While some videos display a high level of visual sophistication, others are notably lacking in this regard. However, in terms of the relationship between texts, signs and figures, the majority of videos demonstrate a commendable degree of coherence and clarity. This observation is consistent across different evaluations, including those pertaining to the legibility of texts in terms of sizes and colours. One of the key strengths of such online videos is that the highest frequencies indicate an optimal distribution of texts, signs and figures, which serves to clarify the topic. In general, with regard to the structure of the videos under consideration, it can be observed that the majority are designed without sufficient technical criteria, in that they do not effectively utilise conceptual (point, line and plane), visual (colour, size, texture, contrast) and relational elements in relation to space. This implies limitations that may result in a deficient didactic transposition. However, this can be avoided by requesting suggestions for reliable videos in accordance with the opinion of specialists.

With regard to the thematic content of the videos, the highest frequencies pertain to the regular or good clarity and conciseness with which the topic is presented and the previous knowledge of the viewer is taken into account. However, the use of formal language to state the Pythagorean theorem is not optimal. The relationship between the lengths of the sides of a right triangle is presented, rather than alternative formulations that avoid erroneous expressions such as "hypotenuse squared" and "sum of the squares of the legs." These errors are repeated in the video and generate cognitive conflict because a segment, such as the hypotenuse, is not squared. Similarly, there is a paucity of visual demonstrations and contextualised applications of the theorem. Furthermore, there is a notable absence of sources, hyperlinks, or tasks designed to facilitate feedback or reinforcement of the topic. Such situations arise because the thematic content of the videos does not align with the intended curricular objectives, but rather reflects the interests and criteria of the designers.

In terms of communication in YouTube videos on the Pythagorean theorem, the highest frequencies indicate that the subject is explained well or optimally, based on texts, signs and figures. However, with regard to allusion to rules for the use of symbols and graphs, the results are distributed between regular or optimal, as is the relationship between mathematical and usual languages. Similarly, the highest frequencies indicate effective communication between geometric and algebraic languages. Additionally, the highest frequency demonstrates a clear and logical communicative sequence. In terms of methodology, the highest frequencies indicate a lack of evidence or deficiencies in terms of stimulating students' interest and the lack of utilisation of technological and didactic resources to induce interactivity or provide feedback for learning.

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