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Video Duration and Engagement in Mathematics Instruction on YouTube: An Analysis of Content-Level Moderators

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Abstract

This study investigates how video length interacts with structural content features to shape user engagement in mathematics instructional videos on YouTube. Drawing on a dataset of 126 highly viewed Turkish-language videos, we examine engagement through three metrics: views (consumptionist engagement), likes (affective engagement), and comments (behavioral engagement). Using descriptive statistics, correlation analysis, and one-way ANOVA, we explore whether video duration varies by educational level, content focus, and mathematical topic, and whether these variations predict engagement. Findings reveal that video length alone does not significantly correlate with any engagement metric, nor does it differ meaningfully across content categories. While longer videos appear more common in secondary education and exam-focused content, these patterns do not translate into higher engagement. The study highlights the need for context-sensitive video design and cautions against one-size-fits-all assumptions about optimal length. Implications are offered for instructional content creators and future research on platform-based mathematics education.

Keywords: YouTube; mathematics education; instructional video; video length; user engagement

1. Introduction

YouTube has rapidly evolved from an entertainment platform into a prominent space for informal learning, particularly in mathematics education. Across grade levels, students increasingly use the platform to revisit concepts, supplement classroom instruction, and prepare for high-stakes exams (Shoufan & Mohamed, 2022; Anisa et al., 2023; Tisdell, 2016). Its accessibility, recommendation algorithms, and expansive library of instructional content have made it a valuable resource for self-directed learners engaging with complex mathematical ideas.

Numerous studies report that mathematics videos on YouTube positively impact learners’ motivation, interest, and academic achievement (Zhafira, 2023; Insorio & Macandog, 2022; Amergus et al., 2021; Baer et al., 2021). However, such outcomes are closely tied to user engagement—a construct widely recognized as central to the effectiveness of digital instruction (Beltrán-Pellicer et al., 2018; Giacomone & Burgos, 2018). As noted by Shoufan and Mohamed (2022), engagement operates as a bridge between content exposure and meaningful learning.

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Research on YouTube-based mathematics engagement generally follows two trajectories. The first includes intervention-based studies where videos are integrated into formal learning contexts, such as flipped or blended classrooms (Nabayra, 2022; Amalric et al., 2023). These studies often focus on how curated or researcher-developed videos influence student engagement in structured environments. A recurring theme in this line of work is the importance of structural features—including content focus, mathematical domain, educational level, and video length—in shaping engagement behaviors (Faye, 2014; Insorio & Macandog, 2022; Amergus et al., 2021; Amalric et al., 2023). However, such studies offer limited insight into how learners interact with instructional content autonomously.

The second strand examines self-directed engagement, emphasizing how learners independently access videos produced by professional content creators. This body of work explores learner preferences and behavior—what types of videos students select (Puga & Aguilar, 2021; Tisdell, 2016), how they evaluate instructional quality (Beltrán-Pellicer et al., 2018), and which content features promote engagement and understanding (Klinger & Walter, 2022; Korntreff & Prediger, 2022; Birgili & Demir, 2024). While offering valuable insight into learner motivation, these studies often overlook how structural characteristics—particularly video length—affect engagement patterns in open, unstructured settings.

Among these features, video length remains an especially critical yet underexplored factor. While some studies examine its role in sustaining attention and managing pacing (Guo et al., 2014; Faye, 2014), and others link it to cognitive load and information retention (Slemmons et al., 2018), few have investigated how video duration interacts with content complexity, educational level, or instructional intent to shape engagement. The prevailing belief that "shorter is better" has been increasingly questioned, especially in mathematics education where extended explanation may be essential for conceptual understanding (Demir & Birgili, 2024; Amalric et al., 2023).

To address this gap, the present study explores the role of video length in shaping both consumption-based engagement (views) and participatory engagement (likes and comments) in mathematics instructional videos on YouTube. Focusing on highly viewed, professionally produced videos, the study examines how video duration interacts with educational level, content focus, and mathematical topic to influence user behavior in self-regulated learning contexts.

This investigation offers two main contributions. First, it deepens our understanding of video length as a mediating factor in digital mathematics learning by analyzing its interplay with content characteristics. Second, it broadens the conceptualization of engagement by positioning structural content attributes—not just learner intent or presentational style—as predictors of observable interaction patterns. In doing so, the study contributes to ongoing efforts to map the factors that drive meaningful engagement with instructional materials on open-access platforms like YouTube.

2. Conceptual framework: User engagement

Understanding user engagement with educational videos on YouTube requires a nuanced view of the types and dimensions of interaction that occur on the platform.

Engagement is more than passive exposure to content; it encompasses varying levels of user involvement, investment, and responsiveness. In digital learning environments, these interactions can be broadly categorized by their degree of intentionality and intensity, forming the basis of the present study's conceptual framework.

Building on foundational models of media interaction (Shao, 2009; Khan, 2017), we distinguish between two primary forms of engagement: passive consumption and active participation. Passive consumption involves behaviors such as viewing a video or scrolling through comments without further action. On YouTube, this is most directly captured through view counts, which serve as indicators of audience reach and initial interest. In contrast, active participation refers to deliberate user actions such as liking, commenting, or sharing content—each reflecting a higher level of emotional or cognitive investment (Khan, 2017; Vazquez-Calvo et al., 2023).

To refine this distinction, we draw on Hollebeek's (2011) multidimensional model of engagement, further operationalized in the context of educational videos by Demir and Birgili (2024). Within the domain of active participation, we identify two sub-dimensions: (1) affective engagement, which reflects emotional reactions such as appreciation or approval, typically indicated by the number of likes a video receives; and (2) behavioral engagement, which captures discursive interaction, including comments, questions, or feedback posted by users.

This classification allows us to map specific YouTube metrics onto theoretically grounded engagement constructs. In our study, view counts represent consumption-oriented engagement, while like counts and comment counts serve as proxies for affective and behavioral engagement, respectively. These indicators—publicly available via YouTube's data infrastructure—provide scalable and comparable measures of how users interact with professional instructional content.

Notably, this study focuses exclusively on videos produced by professional educational content creators. As such, we exclude the dimension of content production (e.g., uploading original content), identified by Shao (2009) as the most intensive form of engagement. Instead, we center our analysis on user behaviors related to viewing and responding to pre-produced content—behaviors that reflect selective access and interaction rather than content creation.

This framework provides the analytical basis for interpreting engagement metrics in relation to structural content characteristics—particularly video length, content focus, educational level, and mathematical topic. Rather than treating these variables in isolation, we explore them as potential moderators of user interaction, offering a more nuanced understanding of how engagement unfolds within the open-access learning environment that YouTube represents.

3. Literature review: Video length and user engagement

Video length has become a central focus in studies of user interaction with educational content on digital platforms such as YouTube. Numerous researchers emphasize that duration is not merely a technical feature but a structural characteristic that significantly influences how information is delivered, processed, and retained (Saurabh & Gautam, 2019; Beautemps & Bresges, 2021; Uo et al., 2014). Video length hence plays a key role in determining the depth of explanation, the pacing of instruction, and the degree to which complex ideas can be scaffolded for diverse learners (Slemmons et al., 2018).

Shorter videos are frequently praised for their efficiency and focus. By presenting a single concept in a concise manner, they are better aligned with limited attention spans and goal-oriented viewing (Faye, 2014; Guo et al., 2014). Guo et al.'s (2014) large-scale analysis of MOOC video data introduced the widely cited "six-minute rule," which suggests that engagement typically drops off after the six-minute mark regardless of total video length. This finding echoes Benjamin's (2002) earlier "ten-minute rule" and has shaped general design preferences toward shorter instructional segments to sustain user attention.

However, research increasingly shows that the relationship between video length and engagement is not uniform. Optimal video duration appears to depend on factors such as topic complexity, viewer characteristics, and learning context. For instance, Beautemps and Bresges (2021) found that science-themed YouTube videos lasting between 7 and 15 minutes were most effective in engaging self-directed learners. Similarly, Saurabh and Gautam (2019) reported that the most popular educational YouTube videos tended to fall within the 10 to 15-minute range, while Faye (2014) found that Malaysian university students preferred videos under 15 minutes, particularly for mathematics content.

Still, longer videos can be equally effective—especially in structured learning environments. Research from Puga and Aguilar (2021) and Tisdell (2016) shows that students in blended settings often value extended videos that offer comprehensive instruction aligned with curricular goals. Meanwhile, brief videos may fall short when it comes to fostering deep conceptual understanding. Amalric et al. (2023), using neurocognitive data, found that although short mathematics videos activated general memory systems, they failed to stimulate the domain-specific brain regions associated with sustained mathematical reasoning, pointing to potential limitations of brevity for certain learning outcomes.

Perceptions of video length are also shaped by users' judgments of relevance and efficiency. In a large-scale study of student reviews, Shoufan (2019) found that users were more likely to express dissatisfaction when videos were unnecessarily long or included off-topic content. Interestingly, Karras et al. (2020) observed that longer videos were often perceived as higher in quality, although this perception did not consistently translate into better engagement metrics.

Importantly, the impact of video length is mediated by user motivation and context. Some users engage with content as part of formal coursework, while others access videos for personal enrichment or exam preparation. These different intentions influence how video duration is perceived and tolerated (Khan, 2017; Gil-Quintana et al., 2020). For example, self-directed learners may prefer mid-length videos that offer depth without cognitive overload, whereas students in formal settings may expect longer, more detailed instruction.

The following sections explore how video length intersects with additional structural content features—specifically educational level, content focus, and mathematical topic—

to shape engagement. These dimensions are examined individually to clarify the layered and context-sensitive nature of user interaction with mathematics instructional videos on YouTube.

3.1. Disciplinary demands and variations in engagement across video lengths

A growing body of research suggests that the relationship between video length and user engagement is significantly shaped by the disciplinary nature of instructional content. In online learning environments, engagement is not merely a function of delivery style or platform architecture; rather, it depends on how well the content aligns with the cognitive demands of the subject matter. This content-specific orientation challenges the assumption of a universal optimal video duration and underscores the need to analyze engagement patterns in relation to disciplinary characteristics.

Evidence from science education highlights the effectiveness of shorter videos. For example, Slemmons et al. (2018) found that middle school students in a flipped science classroom showed higher levels of focus, engagement, and retention when content was delivered in brief, targeted segments. Scientific topics, which are often visual, modular, and fast-paced, lend themselves well to concise formats that facilitate rapid information processing without overwhelming learners. In these contexts, shorter videos enhance comprehension while managing cognitive load.

By contrast, mathematics education presents more complex instructional demands. The discipline relies heavily on abstraction, logical progression, and conceptual depth—features that often require extended instructional time to unpack effectively. Demir and Birgili (2024) emphasize that mathematics-focused YouTube videos can benefit from longer durations, as these allow for detailed exposition, multi-step problem-solving, and clarification of misconceptions. When structured with clear pacing and coherence, longer videos have the potential to foster deeper learner interaction and engagement.

Findings from cognitive neuroscience further support this distinction. Amalric, Roveyaz, and Dehaene (2023) examined the neural responses to short educational videos across different disciplines, including mathematics, biology, and law. Their study revealed that while brief videos activated general memory and attention networks, they did not elicit strong activity in domain-specific regions of the brain associated with mathematical reasoning. This suggests that short-form videos may be inadequate for supporting the kind of deep conceptual processing required in mathematics, particularly for advanced topics such as measure theory or probability.

Together, these studies point to the conclusion that the effectiveness of video length is highly context-dependent. Whereas some subjects benefit from brevity and visual immediacy, mathematics instruction often requires sustained cognitive engagement—best supported by longer, well-paced videos. The alignment between content type and video duration thus emerges as a key design consideration, shaping how learners respond to and interact with instructional materials.

Based on these insights, we investigate the following research question: How does user engagement—measured through views (consumptionist), likes (affective), and comments

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(behavioral)—differ across mathematics instructional videos of varying lengths on YouTube?

3.2. Educational level as a moderator of engagement patterns across video durations

The duration of instructional videos is not only shaped by design preferences or technological affordances but also by the cognitive and developmental demands associated with different educational levels. In mathematics education, the complexity of content increases significantly as learners advance through the school system, often necessitating longer videos to accommodate in-depth explanation, problem-solving, and concept elaboration.

Demir and Birgili (2024) argue that advanced learners benefit from extended instructional formats that allow for the detailed presentation of abstract mathematical ideas and nuanced scaffolding. At the opposite end of the spectrum, younger students tend to engage more effectively with brief, segmented videos. Slemmons et al. (2018) found that middle-grade learners struggled to maintain focus and comprehension when exposed to longer videos. The authors attribute this to learners' limited background knowledge, developing metacognitive strategies, and challenges in processing high-density information.

These findings suggest that video length is not an arbitrary or stylistic choice—it is a response to pedagogical necessity. As students move through educational stages, their ability to handle extended content grows, and video design adapts to that progression. This developmental shift implies that not only should video duration vary by educational level, but so too might patterns of user engagement. How learners respond—through views, likes, or comments—may reflect the alignment (or misalignment) between video length and cognitive readiness. Based on this review, we pose the following research question: How does user engagement differ across instructional mathematics videos targeting different educational levels on YouTube?

3.3. Content focus as a moderator of engagement patterns across video durations

Beyond subject matter and educational level, the **instructional focus** of a video—whether it emphasizes conceptual exposition, problem-solving, or exam preparation—emerges as another key factor influencing optimal video length. This content-specific orientation directly shapes user expectations, cognitive demands, and motivational engagement, thereby playing a critical role in determining how long viewers are willing to interact with a video and what kind of engagement they exhibit.

Shoufan (2019) explored university students' preferences for educational videos and found that content emphasizing applied problem-solving and practical examples generally attracted more positive engagement—especially likes—when video length was well-calibrated. Videos that struck a balance between depth and efficiency received favorable feedback, whereas excessively long videos with redundant elaborations were more likely to receive negative responses. These findings suggest that user tolerance for longer durations increases when the content focus aligns with perceived academic utility.

This alignment becomes even more salient during periods of heightened academic demand, such as exam preparation. Cardoso et al. (2014) and Klinger and Walter (2022) both observed a rise in student engagement with YouTube instructional videos during such periods, particularly those that offer targeted explanations of key concepts and demonstrate problem-solving strategies. Under these conditions, users appear more willing to invest time in longer content when it directly supports their performance goals.

However, not all content focus justifies extended viewing. Amalric, Roveyaz, and Dehaene (2023), in a neurocognitive study involving short mathematics videos on advanced topics, found that although short videos effectively activated general memory areas, they were insufficient to produce meaningful changes in domain-specific brain regions associated with mathematical reasoning. The findings suggest that brief instructional formats may not fully support deeper learning, particularly when content focuses on complex, abstract ideas such as stochastic processes or measure theory. In such cases, longer videos may be pedagogically necessary to facilitate durable conceptual understanding.

These insights collectively highlight a nuanced relationship between what a video aims to teach and how long it should be. Instructional content that involves extended reasoning, multi-step problem-solving, or in-depth conceptual development often requires more time to deliver effectively, and viewers appear to recognize and accept this need when the learning goals are clear. Conversely, simpler procedural content or quick reviews may achieve greater engagement when presented in shorter, more focused formats. Based on these insights, we address the following research question: How does user engagement—measured through views, likes, and comments—differ across mathematics instructional videos with varying content foci on YouTube?

3.4. Mathematical topic as a moderator of engagement patterns across video durations

In mathematics education, user engagement with digital instructional videos is not uniform across content types. Prior research suggests that certain mathematical topics—such as algebra and geometry—consistently generate higher levels of user interaction (Cardoso et al., 2014; Melo et al., 2022; Demir & Birgili, 2024). These differences in engagement metrics point to the influential role of mathematical content areas in shaping how learners interact with instructional videos. However, the extent to which video length interacts with specific topics to impact engagement remains an understudied dimension.

Although previous studies have explored the popularity of certain branches of mathematics, they have rarely examined whether different topics require or benefit from varying video lengths. This omission is notable, given that the cognitive demands of mathematical topics vary widely. For example, instruction in algebra or geometry often involves multi-step reasoning, visual representation, and abstract generalization—all of which may require extended explanations that are better suited to longer video formats. In contrast, topics such as arithmetic operations or fraction manipulation, which are more procedural and straightforward, may be effectively conveyed through shorter, more focused videos.

This interplay between topic complexity and instructional duration raises important questions about how content structure should be aligned with viewer needs. It is plausible that longer videos support deeper engagement with advanced or abstract content, while shorter videos enhance accessibility and comprehension for foundational topics. Yet, without systematic investigation, content creators and educators lack evidence-based guidance on how to match video length with the instructional demands of different mathematical branches.

Understanding how video length and mathematical topic interact to influence user engagement could offer critical insights for the design of instructional materials on platforms like YouTube. This relationship is especially relevant in self-directed learning contexts, where users select content based on perceived usefulness and alignment with their learning goals. Tailoring video length to the specific cognitive and structural characteristics of mathematical topics may improve not only user satisfaction but also educational outcomes. Based on this review, we address the following research question: How does user engagement differ across mathematics instructional videos focusing on different mathematical topics on YouTube?

4. **Method**

4.1. Research Design

This study adopts a cross-sectional, comparative design within the broader scope of quantitative research (Fraenkel et al., 2019). Cross-sectional designs are particularly well suited for identifying patterns and relationships among variables at a single point in time, without aiming to establish causality. This design supports the exploration of how a key structural feature—video length—interacts with other content-related characteristics to influence user engagement with mathematics instructional videos on YouTube.

The study is situated within a comparative analytical framework, using one-way ANOVA to examine how engagement metrics—views, likes, and comments—differ across videos of varying lengths. In addition to video length, the study also considers content focus, educational level, and mathematical topic as grouping variables to explore potential moderating effects. This approach enables the identification of statistically significant differences in engagement based on video structure and content type.

4.2. Context: Mathematics Education and YouTube Use in Turkey

The present research focuses on mathematics instructional videos produced in Turkish, making it essential to contextualize the educational and digital media use in Turkey. Turkey's formal education system comprises 12 years of compulsory schooling, organized as four years of primary education, followed by four years each of middle and high school. Higher education typically spans four years, except for certain extended programs such as medicine. Mathematics is a core subject throughout primary and middle school and remains central to the science track in high schools, though it may be optional for students in other academic pathways.

The mathematics curriculum in Turkey is designed around a spiral structure, with increasing complexity across grade levels. Early education covers arithmetic, basic geometry, and introductory data analysis. Middle school introduces algebra and probability, while high school mathematics expands to include functions, logic, trigonometry, calculus, and advanced statistics.

Access to selective academic opportunities in Turkey is highly dependent on national high-stakes examinations. Middle school students take a central high school placement test, while those completing high school compete in the national university entrance examination. Public sector employment after university is also contingent on a centralized civil service exam. Mathematics plays a prominent role in all of these assessments, making proficiency in the subject crucial for academic and career advancement.

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In recent years—particularly after the COVID-19 pandemic—YouTube has become a dominant platform for accessing supplementary educational resources. Turkish students increasingly rely on YouTube channels that specialize in mathematics to reinforce school learning and prepare for high-stakes exams. This trend has given rise to a commercialized, exam-oriented educational ecosystem on the platform (Arslan et al., 2022; Konukoğlu, 2024; Seçme & Coşkun, 2024). These channels are widely used by self-directed learners, and their content is frequently structured around key curriculum topics, exam preparation, and cognitive scaffolding strategies tailored to different educational levels.

4.3. Dataset Construction and Video Selection Strategy

The dataset for this study was constructed using a systematic keyword-based search procedure aimed at identifying the most-viewed Turkish-language instructional mathematics videos on YouTube. To ensure that the content was relevant, representative, and consistent with the study's focus on video length and user engagement, we employed a multi-step selection process anchored in platform-based search behaviour.

We began by identifying ten commonly used search expressions related to mathematics education in Turkish. These included: mathematics (matematik), learning mathematics (matematik öğrenme), mathematics learning (matematik öğrenimi), learn mathematics (matematik öğren), mathematics teaching (matematik öğretimi), mathematics teacher (matematik öğretmen), mathematics lesson (matematik dersi), mathematics course (matematik kursu), mathematics improvement (matematik geliştirme), and improving mathematics (matematiği geliştir). Each of these terms was individually entered into the YouTube search bar.

Search results were filtered by selecting "video" under the content type filter and sorted by "view count" to prioritize the most popular content. For each term, we examined only the first 100 results. This threshold was intentionally set, as results beyond this point—based on YouTube's recommendation algorithm—tend to drift from the core topic and may include loosely related or entirely unrelated content. By limiting the review to the top 100 videos per term, we maintained topical consistency and maximized relevance across search terms.

Videos were excluded from the dataset if they:

- Focused on news, entertainment, or other non-instructional content;
- Were not presented by individuals in an educational or instructional role;
- Had user comments disabled, which prevented the analysis of participatory engagement;
- Suffered from audio or visual quality issues that could interfere with comprehension.

To avoid duplication, any video appearing under multiple search terms was included only once in the final dataset. After this deduplication process, a total of 126 unique mathematics instructional videos remained. These videos—ranked by view count and filtered for pedagogical quality—form the analytical foundation of this study.

Table 1. Descriptive overview of the dataset

Feature	Median	Mean	The lowest	The highest
Channel subscriber	1.11M	1.65M	202K	6.65M
Channel view count	~221.38M	~312.15M	~38.6M	~936.75M
Length (min)	~35	~53	15	357
Video age (day)	930	990	90	2340

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Video View count	~724K	~992K	~438K	~3M
Video Like	16K	~19K	6K	69K
Video Comment	1.68K	2.38K	254	~9K

~Approximately

Table 1 summarizes key descriptive characteristics of the 126 Turkish-language mathematics instructional videos analysed in this study. The dataset reflects content produced by high-subscriber channels, with a median subscriber count of 1.11 million and a maximum exceeding 6.65 million. The videos vary considerably in length, ranging from 15 to 357 minutes, with a median duration of approximately 35 minutes—highlighting the prevalence of long-format instructional content. The age of the videos spans from 3 months to over 6 years (median = 930 days), indicating a mix of recently uploaded and enduringly popular content. Engagement metrics show that these videos have achieved substantial reach, with median view counts around 724,000 and like counts averaging nearly 19,000. Comment activity also varies, with some videos generating over 9,000 comments, reflecting active viewer participation. These figures provide a robust basis for exploring how video length and content characteristics relate to user engagement on YouTube.

4.4. Data Recording and Coding Framework

To systematically capture the relevant characteristics of each video in our dataset, we developed a detailed coding protocol using a spreadsheet application. For every video, we recorded key metadata, including the video URL, title, associated channel name, subscriber count, and upload date. In addition to these identifiers, we documented numerical values for core variables of interest: video length (in minutes), view count, like count, and comment count. All data were collected directly from the publicly accessible YouTube interface at the time of sampling.

Our analysis also incorporated three categorical variables essential for exploring how content structure relates to engagement: the intended educational level, the instructional focus, and the mathematical topic of each video. The development and coding of these variables were guided by the conceptual framework synthesized in the literature review, ensuring both consistency with prior research and alignment with the goals of the current study.

4.4.1. *Categorizing educational levels*

Each video was classified into one of three educational categories: Early Education, Secondary Education, or Higher Education. This tripartite structure reflects the design of the Turkish education system and captures pedagogical distinctions across student age groups and curricular expectations. Due to the low number of videos explicitly targeting primary-level content (n = 2), the Early Education category combines both primary and middle school levels to enable meaningful statistical comparison, given their shared instructional characteristics.

The classification process followed a stepwise protocol. For many videos, educational level was explicitly stated through grade labels in titles (e.g., “9th Grade”) or playlist organization on the channels. Where explicit labels were absent, we inferred the target level through indirect cues such as exam names or grade-specific references within the video. In cases where ambiguity remained, we reviewed the video content itself, focusing on verbal cues from instructors (e.g., “This is a key concept in 8th grade mathematics”). This triangulated approach allowed for consistent and reliable classification across the dataset.

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4.4.2. *Identifying instructional focus*

To analyze how different pedagogical intentions influence video length and engagement, each video was assigned to one of the following instructional focus categories:

- Concept-Oriented Instruction: Videos that provide curriculum-based explanations of mathematical concepts, often supplemented by one or two illustrative examples for clarity.
- Practice-Intensive Instruction: Videos centered on solving multiple problems within a given topic, typically offering minimal theoretical explanation.
- Exam-Oriented Instruction: Videos designed specifically for exam preparation, integrating topic review with exam-style problems and test-taking strategies.

Classification was based on a combination of metadata (title, description) and video content analysis. Videos that referenced exams directly in the title or emphasized high-stakes preparation scenarios were coded as *Exam-Oriented*. Those that introduced a topic, followed by structured explanation and example-based reinforcement, were coded as *Concept-Oriented*. Videos dominated by sequences of problem-solving with limited conceptual framing were placed in the *Practice-Intensive* category.

4.4.3. *Classifying mathematical topics*

To examine how video engagement may vary by topic, videos were categorized into six major branches of school mathematics, based on frameworks established in mathematics education literature (e.g., Rubenstein & Schwartz, 1999; Carpenter et al., 2003):

- Arithmetic and Basic Mathematics: Includes core operations (addition, subtraction, multiplication, division), fractions, decimals, and percentages.
- Algebra: Encompasses topics such as solving equations, manipulating expressions, and understanding functions and variables.
- Geometry and Trigonometry: Covers properties of shapes, spatial reasoning, angle relationships, and right triangle trigonometry.
- Functions and Calculus: Focuses on linear, quadratic, and exponential functions, as well as introductory calculus topics such as limits and derivatives.
- Probability and Statistics: Involves data representation, interpretation, probability rules, and real-world statistical reasoning.
- Logic and Set Theory: Includes symbolic logic, Venn diagrams, set operations, and foundational reasoning structures used in advanced mathematics.

Topic classification was performed through combined analysis of video titles, descriptions, hashtags, and in-video cues. Many instructors explicitly referenced the subject of instruction (e.g., "Let's solve linear equations today"), which facilitated clear alignment with predefined categories. When titles were ambiguous, video content was reviewed to determine the primary instructional objective. This approach ensured the consistent categorization of videos according to the mathematical domain they addressed.

4.5. Data analysis strategy

All data analyses were conducted using SPSS (Version 25.0). The analysis proceeded in two main stages. First, we used descriptive statistics to summarize the dataset in terms of both continuous variables (e.g., video length, view count, like count, comment count) and categorical classifications (educational level, content focus, mathematical topic). These initial summaries provided a foundational overview of content and engagement patterns across the 126 mathematics instructional videos.

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In the second stage, we employed one-way Analysis of Variance (ANOVA) to examine whether user engagement metrics—specifically views, likes, and comments—differed significantly across categories defined by video length, as well as by educational level, content focus, and mathematical topic. ANOVA is particularly well suited for testing whether mean engagement levels vary across three or more groups, making it an appropriate method for addressing our research questions.

To further explore the role of video length as a continuous predictor of user engagement, we conducted Pearson correlation analyses to assess linear relationships between video duration and each engagement metric. A significance threshold of $p < .05$ was used for all inferential tests. This combination of group-based comparison and correlational analysis allowed for a robust examination of how video length interacts with content characteristics to influence user engagement on YouTube.

5. **Findings**

This section presents the results of descriptive and inferential analyses conducted to explore the relationship between video length and various indicators of user engagement—namely views, likes, and comments—within the context of Turkish instructional mathematics videos on YouTube. The analyses address both distributional patterns across content categories and statistical relationships among video characteristics.

As shown in Table 2, instructional mathematics videos on YouTube exhibit a non-uniform distribution across mathematical branches, educational levels, and content focus. The majority of videos in the dataset are concentrated within Arithmetic and Basic Mathematics (n = 62), followed by Algebra (n = 24) and Functions and Analysis (n = 22). This distribution reflects a strong emphasis on foundational and high-stakes content areas.

Table 2. Distribution of instructional videos by variables

Branches of Mathematics	Educational Level	Content Focus		
		Topic-based instruction (%)	*Focused exercise practice (%)*	*Exam-focused instruction (%)*
Arithmetic and Basic Mathematics (n=62)	Early education	4 (6.45%)	5 (8.07%)	1 (1.61%)
	Secondary	9 (14.52%)	1 (1.61%)	18 (29.03%)
	Higher Education	0 (0.00%)	0 (0.00%)	24 (38.71%)
	All Educational Levels	13 (20.97%)	6 (9.68%)	43 (69.35%)
Algebra (n=24)	Early education	1 (4.17%)	1 (4.17%)	4 (16.67%)
	Secondary	8 (33.33%)	0 (0.00%)	5 (20.83%)
	Higher Education	0 (0.00%)	0 (0.00%)	5 (20.83%)
	All Educational Levels	9 (37.50%)	1 (4.17%)	14 (58.33%)
Functions and Analysis (n=22)	Early education	0 (0.00%)	0 (0.00%)	1 (4.55%)
	Secondary	19 (86.36%)	0 (0.00%)	2 (9.09%)
	Higher Education	0 (0.00%)	0 (0.00%)	0 (0.00%)
	All Educational Levels	19 (86.36%)	0 (0.00%)	3 (13.64%)

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Geometry and Trigonometry (n=11)	Early education	0 (0.00%)	0 (0.00%)	0 (0.00%)
	Secondary	9 (81.82%)	0 (0.00%)	2 (18.18%)
	Higher Education	0 (0.00%)	0 (0.00%)	0 (0.00%)
	All Educational Levels	9 (81.82%)	0 (0.00%)	2 (18.18%)
Probability and Statistics (n=3)	Early education	0 (0.00%)	0 (0.00%)	0 (0.00%)
	Secondary	2 (66.67%)	0 (0.00%)	1 (33.33%)
	Higher Education	0 (0.00%)	0 (0.00%)	0 (0.00%)
	All Educational Levels	2 (66.67%)	0 (0.00%)	1 (33.33%)
Logic and Set Theory (n=4)	Early education	0 (0.00%)	0 (0.00%)	0 (0.00%)
	Secondary	1 (25.00%)	0 (0.00%)	2 (50.00%)
	Higher Education	1 (25.00%)	0 (0.00%)	0 (0.00%)
	All Educational Levels	1 (50.00%)	0 (0.00%)	2 (50.00%)

A closer look at the instructional focus reveals a pronounced dominance of exam-oriented videos within certain topics—particularly Arithmetic, where nearly 70% of all videos fall into the exam-focused category. This trend is especially pronounced at the higher education level, which accounts for almost 39% of arithmetic videos and is exclusively associated with exam preparation content. Similarly, Algebra videos also show a substantial leaning toward exam-focused instruction (58.33%), with contributions across early, secondary, and higher educational levels.

In contrast, Functions and Analysis and Geometry and Trigonometry are predominantly delivered through topic-based instruction, with over 80% of videos in both branches targeting secondary-level students. These content areas seem to support a more conceptual teaching style rather than repetitive practice or exam drilling. Less represented topics such as Probability and Statistics and Logic and Set Theory appear infrequently and are primarily tied to secondary education, with minimal coverage at other levels.

As presented in Table 3, the Pearson correlation analysis revealed strong and statistically significant relationships among the core engagement metrics. Likes and comments showed a strong positive correlation ($r = .765$, $p < .05$), indicating that videos which receive more likes also tend to receive more comments, suggesting a cohesive pattern of participatory engagement. A similar but slightly weaker correlation was observed between likes and views ($r = .646$, $p < .05$), and between views and comments ($r = .455$, $p < .05$), implying that videos with higher exposure generally foster both emotional (likes) and interactive (comments) responses from viewers.

Table 3. Pearson correlation of video metrics and length

		Views	Comments	Likes	Video Length
Comments	Pearson Correlation	1			
Likes	Pearson Correlation	.646**	1		
Views	Pearson Correlation	.455**	.765**	1	
Video Length	Pearson Correlation	.020	-.050	-.098	1

N=126 **p<.05

In contrast, video length was not significantly correlated with any of the engagement metrics. The correlation coefficients between length and views ($r = .020$), comments ($r = –.050$), and likes ($r = –.098$) were all weak and non-significant. These findings suggest that

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video duration alone does not predict the level of user engagement in terms of how much a video is watched or how viewers respond emotionally or behaviorally. This is particularly noteworthy given the widespread assumption in educational video design that longer videos might reduce or enhance user interaction. In this dataset, engagement appears to be driven more by content relevance and quality than by length alone.

These results provide important nuance to the broader investigation by showing that while engagement metrics are tightly interrelated, video length does not show a direct linear relationship with user interaction—underscoring the importance of examining how length interacts with other structural and content features in later analyses.

Table 4 summarizes the comparison of average video lengths across categories defined by content focus, educational level, and mathematical branches. For the content focus, the longest average video length was observed in the Focused Exercise Practice category (M = 89.49 minutes, SD = 105.5). This mean duration was notably longer compared to videos categorized as Topic-Based Instruction (M = 50.57 minutes, SD = 59.91) and Exam-Focused Instruction (M = 52.56 minutes, SD = 44.95). Despite these noticeable mean differences, the ANOVA analysis indicated that the variation across these groups was not statistically significant (F = 1.525, p = .222).

Table 4. Comparison of Video Length Across variables

		N	Mean (video length)	Std. Deviation	F	p
Content focus	Topic-based instruction	54	50.57	59.91	1.525	.222
	Focused exercise practice	7	89.49	105.5		
	Exam-focused instruction	65	52.56	44.95		
Educational level	Early education	16	52.90	74.74	.594	.554
	Secondary	83	57.22	54.29		
	Higher education	27	43.61	50.64		
Branches of mathematics	Arithmetic and Basic Mathematics	62	53.74	53.35	.316	.903
	Algebra	24	45.67	32.41		
	Functions and Analysis	22	65.32	84.52		
	Geometry and Trigonometry	11	51.05	61.89		
	Probability and Statistics	3	58.50	47.31		
	Logic and Set Theory	4	42.75	7.449		

When comparing video lengths by educational level, the longest average duration was associated with videos aimed at secondary education (M = 57.22 minutes, SD = 54.29). This average was slightly higher than videos targeting early education (M = 52.90 minutes, SD = 74.74) and substantially higher than those for higher education (M = 43.61 minutes, SD = 50.64). Nevertheless, this variation did not yield a statistically significant difference (F = .594, p = .554).

Across different branches of mathematics, videos covering Functions and Analysis had the highest average length (M = 65.32 minutes, SD = 84.52). The next longest durations

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were found in videos focusing on Probability and Statistics (M = 58.50 minutes, SD = 47.31) and Arithmetic and Basic Mathematics (M = 53.74 minutes, SD = 53.35). In contrast, Logic and Set Theory videos had the shortest average length (M = 42.75 minutes, SD = 7.45), followed closely by videos addressing Algebra (M = 45.67 minutes, SD = 32.41). However, these differences across mathematical branches were not statistically significant (F = .316, p = .903).

Overall, while descriptive analyses revealed distinct mean differences in video length among content categories, educational levels, and mathematical branches, the ANOVA tests confirmed that these variations were not statistically significant.

6. **Discussion**

In this study we focused on how video length interacts with both user engagement metrics—views, likes, and comments—and content-related variables such as educational level, content focus, and mathematical topic. Rather than presenting a general discussion, this section is structured around the central research questions guiding the study.

6.1. Engagement metrics and video lengths

Our findings provide critical insights into the nuanced relationship between video length and user engagement metrics in the context of mathematics instructional videos on YouTube. Contrary to widely cited frameworks such as Guo et al.'s (2014) "six-minute rule" and Benjamin's (2002) "ten-minute rule," our data indicated no statistically significant correlation between video length and engagement metrics. Specifically, the Pearson correlation analysis demonstrated negligible relationships between video duration and views (r = .020), likes (r = -.098), and comments (r = -.050), all statistically insignificant. This pattern challenges the assumption prevalent in the literature that shorter instructional videos inherently sustain greater viewer attention and engagement due to limited attention spans (Faye, 2014; Guo et al., 2014).

An important interpretation of these results emerges when considering the findings of Amalric et al. (2023), who suggested that shorter mathematics videos, despite activating general memory processes, often fail to engage domain-specific cognitive mechanisms deeply enough to facilitate sustained mathematical understanding. Our findings align with this perspective, suggesting that shorter durations alone do not guarantee enhanced engagement, particularly in domains requiring conceptual depth and sustained cognitive processing, such as mathematics. The absence of a significant correlation in our study could reflect viewers' prioritization of content relevance and instructional quality over video brevity. In other words, viewers appear willing to engage extensively with longer videos when these videos effectively support deeper cognitive processing and conceptual comprehension, echoing Demir and Birgili's (2024) assertion that longer, thoughtfully structured mathematics videos can foster high levels of engagement.

Further, the ANOVA analysis of video length across various categories (content focus, educational levels, and mathematical branches) yielded no significant differences. This finding suggests that video length preferences in mathematics instructional content may not be universally determined by these structural characteristics alone. While Beautemps and Bresges (2021) and Saurabh and Gautam (2019) reported optimal durations of 7–15 minutes for science-oriented videos, our study revealed a wide range of mean lengths, particularly noting that videos categorized under focused exercise practice (mean duration 89.49 minutes) tended to be considerably longer than those focusing on topics (mean duration 50.57 minutes) or exams (mean duration 52.56 minutes), although these differences were not statistically significant. This discrepancy indicates that mathematics instructional videos may inherently vary more in duration without substantially impacting engagement metrics.

Moreover, despite Karras et al.'s (2020) findings suggesting that longer videos are often perceived as higher quality, our results indicate that perceived quality linked to length did not translate into higher engagement measures. Given our sample consists of videos with already high viewership, it is possible that factors such as content clarity, instructional approach, and alignment with viewers' immediate educational needs play a more significant role in user engagement than video length alone. Indeed, Shoufan (2019) emphasizes that viewer satisfaction, and thus engagement, depends heavily on efficiency and content relevance rather than duration per se. Therefore, the lack of significant correlation between length and engagement metrics in our data likely reflects this complex interaction.

6.2. Educational level and video durations

Although previous research suggests that instructional video length tends to increase with educational level (Demir & Birgili, 2024), our findings do not fully confirm this trend in the context of mathematics videos on YouTube. As reported in Table 4, the average video length was highest for secondary education videos (M = 57.22 minutes), followed closely by early education (M = 52.90), with higher education videos being the shortest on average (M = 43.61). However, these differences were not statistically significant ($F = 0.594$, $p = .554$), indicating that in our sample, video duration did not systematically vary by educational level.

This non-significant pattern challenges the assumption that higher cognitive demands at upper educational levels consistently lead to longer video formats. One possible explanation is that creators targeting higher education may deliberately favor brevity and conciseness, aiming to deliver content in more efficient formats suitable for mature, self-directed learners. This would align with the argument by Shoufan (2019) that user satisfaction in advanced instructional contexts is often tied to efficiency and topical relevance rather than duration. Additionally, the increasing availability of modular or topic-specific tutorials at the higher education level may encourage microlearning-style video design, even for complex topics.

At the same time, the relatively long durations observed in secondary education videos might reflect an effort to balance conceptual explanation with exam-focused practice, particularly given the strong presence of high-stakes test preparation in Turkey's secondary-level mathematics education (Arslan et al., 2022). As such, longer videos at this level may serve both instructional and evaluative functions—covering core topics while integrating test-oriented strategies. This dual purpose could help explain why secondary-level videos displayed both longer durations and substantial representation in exam-focused content.

Interestingly, early education videos, though designed for younger learners, also showed substantial length (M = 52.90), contradicting literature suggesting that younger students benefit more from shorter, segmented instruction (Slemmons et al., 2018). This misalignment between cognitive load and video duration may point to a disconnect between pedagogical research and actual production practices on YouTube.

Despite these descriptive trends, our statistical analysis did not detect significant variation in engagement metrics by educational level. As reported in Table 3, there was no significant correlation between video length and any engagement metric, nor did ANOVA results support systematic differences in engagement across educational levels.

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This finding contrasts with studies such as Khan (2017) and Gil-Quintana et al. (2020), which suggest that learner motivations and readiness can shape how content length is experienced. In our dataset, user interaction patterns appear decoupled from educational level, indicating that engagement may be influenced more by topic, instructional style, or platform visibility than by formal audience designation.

6.3. Mathematical topic and video durations

Our findings indicate that while average video length does vary across content foci, these differences are not statistically significant ($F = 1.525$, $p = .222$), as shown in Table 4. Among the three instructional formats, videos categorized as Focused Exercise Practice exhibited the longest mean duration (M = 89.49 minutes), followed by Exam-Focused Instruction (M = 52.56 minutes) and Topic-Based Instruction (M = 50.57 minutes). Despite the lack of significance, these descriptive differences suggest potential patterns that align with theoretical expectations regarding content-driven demands on duration.

The elevated duration of exercise-focused videos likely reflects their procedural emphasis—such videos tend to include extended problem sets or walkthroughs, requiring time for iterative practice. This finding is compatible with Shoufan's (2019) observation that users appreciate longer videos when they offer sustained, application-oriented engagement, particularly when problem-solving is central to the design. Similarly, the relatively long duration of exam-focused videos may reflect a blend of conceptual review and practice tasks, catering to users with explicit performance-oriented goals. This aligns with Cardoso et al. (2014) and Klinger and Walter (2022), who found increased student willingness to invest time in instructional videos during exam periods, especially when content is closely tied to assessment needs.

By contrast, topic-based instruction, though similar in duration to exam-focused content, likely demands more cognitive processing time per concept due to its emphasis on abstraction and explanation. Interestingly, despite this cognitive load, such videos were not longer on average—suggesting either that creators strive to maintain brevity in conceptual videos or that viewers may disengage if abstract material is not presented with precision and economy. This reflects Shoufan's (2019) additional point that user tolerance for video length is contingent not only on the topic but on perceived efficiency and focus within that topic.

Crucially, our findings also reveal that none of the engagement metrics significantly correlate with content focus or video length. This suggests that the alignment between video length and content type may shape instructional delivery more than it drives user response. In other words, creators appear to vary length based on what the content requires pedagogically, but this does not necessarily yield differences in how viewers interact with the videos.

Taken together, our analysis extends the existing literature by showing that content focus does influence average video duration in meaningful ways, even if user engagement patterns do not reflect these adjustments in a statistically significant manner. This points to a subtle disjunction between what instructional content demands and what audiences reward through engagement metrics—a tension with important implications for creators who must navigate the competing demands of instructional depth, viewer retention, and algorithmic visibility.

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6.4. Mathematical topic and video durations

Although previous research emphasizes that engagement metrics tend to vary across mathematical topics (Cardoso et al., 2014; Melo et al., 2022; Demir & Birgili, 2024), our findings did not reveal significant differences in video length across branches of mathematics (F = .316, p = .903; see Table 4). However, descriptive statistics offer meaningful patterns. Videos on Functions and Analysis had the highest average duration (M = 65.32 minutes), followed by Probability and Statistics (M = 58.50), and Arithmetic and Basic Mathematics (M = 53.74). In contrast, videos focused on Logic and Set Theory (M = 42.75) and Algebra (M = 45.67) were shorter on average.

These duration patterns reflect the varying cognitive and structural demands of mathematical content. Functions and Analysis, often associated with multistep reasoning and symbolic abstraction, may require extended instructional time to scaffold complex ideas and demonstrate application. This is consistent with Amalric et al. (2023), who argue that short videos may fail to sufficiently activate domain-specific cortical regions, particularly in abstract or advanced mathematical content. Our data suggest that creators may intuitively respond to such demands by producing longer videos for these topics, even if user engagement does not vary accordingly.

Interestingly, Arithmetic, while typically regarded as procedural and foundational, also showed relatively long average durations. This may be explained by its strong association with exam-focused instruction in our dataset, where videos often cover extensive problem sets or exam simulations. In this sense, the longer durations observed in arithmetic videos may reflect curricular pressure rather than cognitive complexity, aligning with findings by Demir and Birgili (2024), who noted the exam-centric nature of mathematical content on YouTube.

Conversely, Algebra, despite being conceptually rich and frequently cited as a high-engagement topic (Melo et al., 2022), was associated with shorter average video lengths. This discrepancy may point to a content delivery strategy favoring modularization, where algebraic procedures are broken into short, digestible segments. Alternatively, it may reflect user preferences for briefer algebra tutorials, especially when learners approach content for quick reference or targeted clarification.

It is important to note that, despite these descriptive trends, no significant correlation was found between video length and engagement metrics for any mathematical topic. This indicates that longer or shorter videos within a topic do not inherently attract more or less user interaction, suggesting that users may prioritize factors like presentation clarity, instructor style, or topical relevance over video duration alone.

Collectively, our findings highlight a mismatch between pedagogical necessity and audience behavior. While certain topics appear to warrant longer durations based on their conceptual demands, this adjustment does not consistently result in higher engagement. This insight extends the current literature by emphasizing that video length may reflect instructional complexity without necessarily shaping user response, at least as measured through publicly visible metrics on YouTube. It also underscores the need for further investigation into how duration, content structure, and presentation quality jointly influence user experience, particularly in self-directed learning environments where engagement is both selective and context-dependent.

7. **Conclusions and implications**

This study examined how video length interacts with various structural content features—namely educational level, content focus, and mathematical topic—to shape user engagement with mathematics instructional videos on YouTube. Drawing on a dataset of 126 highly viewed Turkish-language videos, engagement was operationalized through three publicly available metrics: views (as consumptionist engagement), likes (as affective engagement), and comments (as behavioral engagement). The findings suggest that video length alone does not significantly predict user engagement. Neither correlation analyses nor ANOVA results showed a statistically significant relationship between video duration and any engagement metric. This challenges prevailing assumptions in the literature that shorter videos inherently generate higher engagement and highlights the importance of contextual factors over fixed design heuristics.

Although descriptive statistics indicated that video duration varied by educational level, content focus, and mathematical topic, these differences did not reach statistical significance. For instance, secondary-level videos and those focused on exam preparation tended to be longer on average, while higher education videos were more concise. Similarly, topics like functions and analysis showed greater average lengths, consistent with their conceptual complexity. However, these structural variations in video design were not reflected in user interaction patterns, suggesting a potential disconnect between pedagogical intent and measurable engagement. These findings extend prior research by emphasizing that engagement metrics alone may not capture the nuanced ways learners interact with content, particularly in self-directed learning environments.

Based on these insights, several practical implications emerge. First, rigid adherence to universal video duration recommendations—such as the “six-minute rule”—may be inadequate in instructional contexts that demand conceptual depth and cognitive elaboration. Content creators should instead tailor video length to the demands of the mathematical topic, the developmental stage of the intended audience, and the specific instructional goals. Second, while longer videos may be pedagogically appropriate for abstract or exam-intensive topics, their effectiveness in attracting engagement will likely depend on other factors such as pacing, clarity, and perceived efficiency. Modularizing content into smaller, focused units may offer a strategy for accommodating varying user preferences without sacrificing instructional rigor. Lastly, creators should be cautious in interpreting engagement metrics, as views, likes, and comments may reflect broader platform dynamics or audience motivations that are not directly tied to content quality or learning value.

Despite its contributions, the study has several limitations. First, the analysis was limited to publicly visible metadata provided by YouTube, which may not fully capture deeper forms of engagement such as sustained attention, cognitive involvement, or learning outcomes. Second, the study focused exclusively on Turkish-language videos, which, while contextually rich, may limit the generalizability of the findings to other linguistic or cultural settings. Third, the engagement metrics analyzed are shaped not only by content design but also by algorithmic visibility, thumbnail aesthetics, and channel popularity—factors that were not directly controlled in this study. Finally, the cross-sectional nature of the data limits inferences about causality or changes in engagement patterns over time. Future research could address these limitations by incorporating mixed-methods approaches, measuring learning gains, and examining additional variables such as instructor delivery style, audience retention data, or algorithmic reach.

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