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Creating Animations for Maths Teaching

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Creating Animations for Maths Teaching

A praxis-oriented discussion paper about the use chatbots for the creation of mathematical animations with Manim

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ABSTRACT:

This discussion paper investigates short Manim based animations as reusable learning objects for undergraduate service mathematics and addresses four questions on pedagogical value, production effort, the role of generative AI, and design principles. A part of our contribution is a reproducible workflow, including concrete engineering choices for camera orientation, label management, and render time control through a quality flag. The paper further outlines a git centered development process with AI assistants and records practical guidance on Manim Community Edition usage and agentic code generation.

A small deployment was conducted in a small Analysis course within a civil engineering dual program in the summer semester 2025 at the IU Internationale Hochschule. Likert scale results indicate positive perceptions of relevance and clarity, and YouTube analytics show peaks in viewing near release dates during the lecture period from April 2025 to June 2025 with no spike during the exam phase. This pattern suggests use for in term understanding rather than last minute exam preparation. Qualitative comments cite improved visualization of abstract content and clearer answers to why certain topics matter, with a request for tighter links to worked examples.

The paper synthesizes design considerations for guided and self-guided consumption, timing and narration, and constraints imposed by small displays, and motivates reuse and open sharing of source-code-based animations. Limitations include a single site context, small sample, and the absence of objective learning outcome measures.

KEYWORDS:

Mathematics, Manim, Animations, Teaching, Education, generative AI

JEL classification: JEL I23

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1 Introduction

1.1 MULTIMODAL LEARNING AND CHALLENGES IN SERVICE MATHEMATICS

Research in cognitive science has shown that students learn more deeply when we provide them with multimodal input. For example, students learn much more deeply with a combination of words and pictures rather than words alone (Mayer, 2009). This leads to the well-known method of sketchnoting where visuals and texts are combined to enhance fun and efficiency in note taking and communication, and is also valid in STEM fields (Marquardt & Greenberg, 2012; Paepcke-Hjeltness et al., 2019).

In STEM fields, mathematics in particular, we have the general challenge that we are dealing with highly abstract or complex topics. While mathematicians get trained on working with such topics over a long period of time by creating abstraction layers and deep understanding of the underlying logic, students in mathematic service classes[1] often lack the required mathematical foundation to fully understand what is going on (Burazin et al., 2021; Tang et al., 2025; Tossavainen et al., 2021). This is often combined with limiting beliefs – such as “I was never good at mathematics” - and anxiety about mathematics (Charalambides et al., 2023) and a deep misunderstanding of the relevance of mathematics for their chosen subject (Sazhin, 1998). Instead of a deep conceptual understanding, mathematics are often perceived or remembered as a collection of rules, procedures, theorems, definitions and applications that are not well integrated into the actual curriculum (Abdulwahed et al., 2012; Kyle & Kahn, 2008).

Using videos or annotated animations can create concrete representations that make abstract ideas more accessible, while also preventing cognitive overload on students. Studies note that video demonstrations allow learners to see practical, close-up illustrations of concepts – for instance, a geometric transformation or a real-world application of a formula – which would be nearly impossible to adequately describe through text (Carmichael et al., 2024; Charalambides et al., 2023). They can be used for bridging the gaps between the actual requirements of a class and the fact that there always are underprepared students that often feel too embarrassed to ask questions in class (Lewis et al., 2023). These types of videos can be consumed at the students pace, on demand, making it much easier to prepare for classes and exams (Charalambides et al., 2023).

Moreover, there is a further variable that can impact mathematical competence and that is the role that fast intuitive thinking (generally described as System 1, S1) versus slow reflective and conscious thinking (also referred as System 2, S2) has on the development of mathematical skills, and how a better understanding of this role can be applied to mathematics education (Kahneman, 2011, 2018).

Gómez-Chacón et al. (2014a) analyzed the interaction of S1 and S2 as a function of other variables such as mathematical beliefs and cognitive reflection. They found that such variables may explain and predict performance in mathematics.

Within this context, we wish to explore the potential that videos have to either promote and/or hinder cognitive reflection and reasoning in order to foster a beneficial interaction between S1 and S2 as well as promoting belief systems that positively correlate with high accomplishment in mathematics.

[1] Courses designed to provide students from non-mathematics majors with the mathematical knowledge and skills relevant to their primary field of study.

1.2 DIGITAL TOOLS FOR VISUALIZING MATHEMATICS

To tackle these problems, a multitude of tools have recently gained importance in teaching math. Studies consistently find that dynamic geometry significantly enhances students' conceptual understanding of complex mathematical concepts like calculus and geometry by. It also notably increases student engagement, curiosity, and motivation (Kado, 2021; Ocal, 2017; Pant et al., 2024; Zulnaidi & Zamri, 2017). Similarly, research shows that function plotting effectively improves students' conceptual grasp of algebra and functions by enabling interactive visual verification of solutions. Although it strongly enhances learning outcomes, improvements in students' attitudes toward mathematics are less consistent (Chechan et al., 2023; Farmer, 2024; Madrilejos, 2024; Pope, 2023).

Learning environments in multiple kinds have been attempted to reach objectives such as personalized learnings and independent progression. This appears particularly necessary, as reflection at a cognitive level must be employed whenever issues arise. This is what is claimed in the review (Vidergor & Ben-Amram, 2020) about the Khan Academy learning platform where small video chunks (which perform mostly like pieces of classroom lessons) are consumed following the learners' progress: Their paper demonstrates a greater self-guidance.

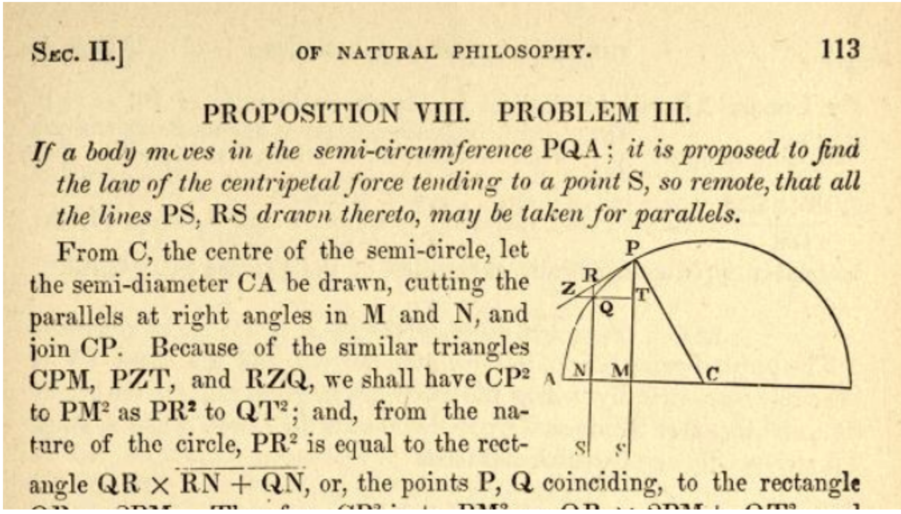
Jupyter Notebooks and their widgets can help students visualize abstract mathematical concepts interactively and enhance the exploratory learning experiences. While quantitative gains vary, qualitative feedback consistently highlights increased student engagement and improved conceptual visualization, especially in service courses like Business Calculus (Spencer-Tyree et al., 2024; Yavuz Temel et al., 2025). Interactivity allows students to *"visualize and manipulate data, or to explore different visual representations of concepts, illuminating the relationships"* between them (Du et al., 2024).

Fields (2024) demonstrated the use of **Manim** (the open-source math animation library popularized by the 3Blue1Brown video series (Sanderson, 2015/2025) for creating instructive math animations. In a conference poster, he notes that animations can convey complex ideas efficiently: *"If a picture is worth 1000 words, how many words is an animation worth? … a tremendous amount of mathematical content can be conveyed in a short time using animations."* Manim scripts let teachers program scenes (e.g. moving graphs, geometric constructions) to illustrate abstract concepts dynamically. The report emphasizes that well-crafted animations make abstract math visible and engaging, though there is a learning curve for instructors new to coding (Akhilesh et al., 2024; Castillo & Sánchez, 2023; Coluci, 2021; Marković & Kaštelan, 2024).

Visualizing a mathematical idea often involves highlighting the variation of some quantities and the variation of related quantities. While representations such as tables make it possible to display such quantities, they require a cognitively demanding process and is often done superficially. Instead, displaying a mechanics-like relationship where an object moves together with a moving object makes it possible to grasp the relationships better. This can be done in dynamic geometry according to the variation principle in (Leung, 2008) but could also be done in a predefined sequence, demonstrating to the viewer the set of possible values and their related values.

This idea of displaying sequences of moving points is natural in the learning process of a child and has been formalized by multiple mathematical works. One of the most seminal works in this direction is the

Principles of Natural Philosophy of Sir Isaac Newton (Newton et al., c1846), p. 113, whose graphics and mathematical approaches show clearly the iterative steps and their measures. An example is given in Figure 1. Newton introduced this step-by-step approach to introduce concepts such as the derivative.


SEC. II.] OF NATURAL PHILOSOPHY. 113

PROPOSITION VIII. PROBLEM III.

If a body moves in the semi-circumference PQA; *it is proposed to find the law of the centripetal force tending to a point* S, *so remote, that all the lines* PS, RS *drawn thereto, may be taken for parallels.*

From C, the centre of the semi-circle, let the semi-diameter CA be drawn, cutting the parallels at right angles in M and N, and join CP. Because of the similar triangles CPM, PZT, and RZQ, we shall have CP^2 to PM^2 as PR^2 to QT^2; and, from the nature of the circle, PR^2 is equal to the rectangle $QR \times \overline{RN + QN}$, or, the points P, Q coinciding, to the rectangle

Figure 1: Extract from Principia (Newton et al., c1846) demonstrating the stepwise approach.

While Newton made manual calculations for each value and displayed each step on a picture, contemporary technology makes it possible to perform many more calculations and record animated pictures; it is thus natural to display a mathematical relationship as the joint movement of points.

1.3 RESEARCH QUESTIONS AND CONTRIBUTION

In this discussion paper, we want to address the following **research questions**:

1. What pedagogical value add short, Manim-based videos to mathematical service lectures in distance learning as well as in-class dual studies lectures?
2. How steep is the production learning curve of Manim and is it worth the effort?
3. How can we make use of generative AI to enhance the production process of Manim videos?
4. What are the main aspects to consider when designing videos to make the learning journey more effective and interactive?

In this paper, we present a practical workflow and best practices together with a small-scale student survey about the usage of our videos.

The remainder of this paper is organized as follows. **Section 2** discusses the dual-process theory in mathematics education, focusing on the interplay between fast, intuitive cognition (System 1) and slow, reflective reasoning (System 2), and explores how mathematical beliefs and motivation influence learning outcomes. **Section 3** presents a concrete example of the workflow for creating a Manim video, detailing the process from mathematical concept to animated visualization, and highlighting challenges encountered in translating theoretical ideas into dynamic scenes. **Section 4** addresses the integration of large language models and AI assistants into the development of Manim videos, summarizing practical guidelines, pitfalls, and best practices that have emerged when leveraging AI to accelerate and structure video production. **Section 5** turns to the pedagogical design of mathematical videos, emphasizing the importance of curiosity-driven storyboarding and reflective questioning to foster deeper engagement and conceptual understanding. **Section 6** examines the application of such learning videos in distance and dual study contexts, comparing guided and self-directed video consumption and considering implications for accessibility and didactic integration. **Section 7** reports on a mini survey conducted with students who engaged with the videos, providing both quantitative and qualitative insights into their experiences, motivations, and perceived benefits. **Section 8** offers a discussion of the main findings, synthesizes the strengths and limitations of the approach, and sketches directions for future research and the broader adoption of AI-assisted, animation-based learning resources in mathematics education.

2 Ways of Thinking, Fast and Slow

2.1 DUAL-PROCESS THEORY IN MATHEMATICS EDUCATION

Kahneman (2011) proposes an interesting approach to distinguish fast, mostly automated unconscious decisions and responses (related to our intuition), versus slow and conscious analytical reasoning when solving mathematical problems and other strategic planning. He coined these two ways of thinking *System 1*, associated with fast intuitive thinking, and *System 2* associated with slow analytical thinking.

In the context of developing better resources and techniques available to mathematics educators and with the aim of enhancing the effectiveness of teaching as well as improving learning outcomes, we find the distinction of these two types of thinking of relevance.

We would like to study activities, resources and rewards systems that can encourage the activation of system 2 as well as instilling the identification of a functioning system 1.

In addition, we wish to reflect on what would be an optimal co-operation or group effort between both systems, always in the context of mathematics and applied mathematics disciplines. For example, by encouraging further reflection upon the potential correctness of answers provided by system 1.

We wish not to suppress the use of system 1. In the end, many great inventions and ideas own its discovery to systems 1, but only when overtaken by a vigilant and “ready to refine” system 2.

There is consensus among researchers that to solve well-defined mathematical problems, system 2 shall be engaged; this is well exemplified in many research studies and tests such as the CRT test (Frederick, 2005). The problem of the bat and the ball[1] is one of many such problems designed to create an intuitive erroneous answer versus a well-reasoned correct answer.

2.2 MATHEMATICAL BELIEF SYSTEMS AND LIMITING BELIEFS

The work of (Gómez-Chacón et al., 2014b) highlights the relevance and impact that several factors have on the aptitude of people to solve mathematics problems. These factors include not only mathematical knowledge, but also factors associated to self-confidence and a set of beliefs associated to mathematics. We place our focus on the latter, generally referred to as “mathematical beliefs”.

[1] Bat and the ball: a math riddle consisting of asking for the price of a ball knowing that a bat and the ball together cost $1.10, and the bat costs $1 more than the ball.

The author beliefs that teachers and content creators, particularly video makers, might benefit from familiarizing with what is known as the “Mathematics beliefs system”. Understanding how others who struggle with math feel like can assist in developing more empathetic approaches that may, in turn, increase motivation and encourage active engagement among viewers.

Because the knowledge about mathematical belief system is large, we have requested ChatGPT 4o in July 2025 to describe what “mathematics belief system” means: the following list of items were reported as key components of a Mathematical belief system:

“1. **Beliefs about the nature of mathematics:**

Is math a fixed set of rules and procedures?

Or a creative, dynamic field of exploration?

2. **Beliefs about learning mathematics:**

Can mathematical ability grow with effort (growth mindset)?

Or is it something you either “have or don’t have” (fixed mindset)?

3. **Beliefs about teaching mathematics:**

Is the teacher a transmitter of knowledge?

Or a facilitator guiding students’ reasoning and discovery?

4. **Beliefs about oneself:**

“I’m not a math person.”

“I need to understand why something works.”

“Making mistakes is part of learning math.”

We acknowledge that some individuals may be particularly susceptible to the above mathematical limiting beliefs such as “I am not a math person” or “I’ve never been good at math” together with a fixed mindset. Regardless of the specific reasons why someone may have arrived to those beliefs, these set of unconstructive mathematical beliefs may act as a priming that has the potential to significantly influence students’ performance. (Yeager et al., 2019) showed in a large case study that even a short growth mindset intervention can significantly increase the performance for lower-achieving students.

We wish to propose that this set of unconstructive beliefs may have an effect similar to the prior-task failure effect (Lemaire & Brun, 2018; Smith et al., 2006).

Acknowledging this effect may be the first step at designing potential tools that can effectively address this issue and help the outline of mitigating strategies.

2.3 DEEP UNDERSTANDING, KNOWLEDGE GAPS, AND SELF-REGULATION

It is worth mentioning that mathematics is inherently verifiable with concepts building up further on other concepts. This implies that having a gap somewhere in mathematics will make it difficult to impossible to understand later concepts. That is, the comprehension of new knowledge typically requires that earlier concepts are well understood. For instance, even with no previous knowledge, we may be able to memorize multiplication tables effectively. However, with no understanding of addition, one will not be able to grasp the logic behind the construction of multiplication tables. To do so, one must know how to add and recognize that multiplication is a compact notation for repeated addition. If we only learned the tables purely by rote and our memory fails, we have no way to fill in any gaps or deduce the values. In other words, memory assists in making our arithmetic more agile, but it is deep understanding[1] what makes the computation reliable. Mathematics is particularly sensitive to gaps in our understanding, and it is therefore vital to construct knowledge on solid foundations, that is deep understanding rather than rote learning and memorization.

Moreover, deep understanding plays a relevant role in building up positive beliefs and confidence. In mathematics, this deep understanding is most likely achieved when students engage in a self-regulated learning experience driven by their own inner motivation and curiosity. The term “motivational regulatory strategies” is described by Monique Boekaert in her work “Self-regulated **learning** at the junction of cognition and **motivation”** (Boekaerts, 1996): “*Effective strategy use, initiative, persistence, confidence, resourcefulness and self-reactivity to task performance outcomes.*”

This is of particular importance in mathematics, since it takes time and effort to understand the high level of abstraction written in a very compactified way. Motivation and curiosity are vital components so that the process is understood and enjoyed rather than endured.

2.4 DESIGNING VIDEO PROMPTS TO ACTIVATE SYSTEM 2

It is therefore important when designing videos to incorporate elements that instill these attributes. For example, encouraging students to pause the video, solve a simple problem and inviting them later to reflect on the task performance outcome. It is central that students see the relevance of understanding why some answers are wrong, rather than simply acknowledging that the answer is incorrect and correcting it. And it is fundamentally important that they are curious about it.

It is the reflection and identification of the internal flaw in their logic or reasoning what makes the difference between superficial and deep understanding. The latter, only the student can identify with initiative, persistence and confidence as only they know their internal reasoning in detail.

Furthermore, in the context of mathematics, the idea that every mistake is an opportunity to learn is only true if we understand in depth why we made the mistake and why that is incorrect. It is the why question that leads to a deep understanding rather than the acknowledgement that something is incorrect and that it should be done in another way. For instance, in the bat and ball problem, simply acknowledging that the answer is not 0.1 and it is 0.05 will not increase the chances of finding a correct answer to a different problem. It is the recognition that the approach to the problem (simply saying a number that pops out in our head) is incorrect because the answer makes no sense whatsoever, as it does not correspond to the statement of the problem (the bat and the ball costs 1.1$). Only the development of a procedure that uses deductive reason will increase the chances of finding a correct answer when facing a different problem.

[1] The ability to grasp the underlying connections and principles of mathematical ideas so that one can flexibly apply them, explain them in multiple ways, and transfer them to new or unfamiliar situations

In math rarely is anything arbitrary, and most information is linked through deductive reasoning. Even some definitions that seem arbitrary are motivated by logical consistency or usefulness within a broader theory. Therefore, most mistakes are likely due to flaws in the deductive reasoning or simply lack of it.

Inviting students by formulating question situations within the videos in order to stimulate reflection so that they discover why the proposed solution is correct or incorrect is of the utmost importance to trigger system 2 and encourage students to use deductive reasoning.

(Frederick, 2005) suggests that intuitive responses (system 1) are the default responses and that unless some effort is made to think further, e.g. verification of the answer, system 2 is not activated. Moreover, (Gómez-Chacón et al., 2014b) comment on the presence of a possible regulating system that controls or resolves potential inconsistencies or conflicts between systems.

Studies show that the enjoyment of thinking positive correlates with academic achievement (Strobel et al., 2024), **suggesting that it** may also play a relevant role in the engagement of system 2.

This is consistent with the idea that system 1 is fast and system 2 slow. When a task is pleasant, it makes sense that system 2 is engaged to prolong the pleasure.

Understanding the mechanism that triggers the activation of system 2 is of interest to mathematics educators as this is key to solving problems using reasoning skills rather than quick pattern recognition (system 1). Thirst for understanding, inner motivation and math's curiosity are proposed to be the key elements in this process.

In addition, raising awareness that our intuition can lead us to a wrong answer can help in activating a vigilant system 2. Including a relevant example at the beginning of a video where students can experience that their intuition is incorrect may help in raising this awareness.

3 Example process of using AI to learn and create Manim videos

3.1 VISUALIZING AND ENHANCING THE VISUALIZATION

We describe the somewhat complicated workflow for our video about the formula of a revolving body[1]. The full code for the video can be found on GitHub[2].

The basic idea to derive the formula is straightforward. We start from the discrete level by the steps:

- Identify for a point $x_i \in D$ that a circle of a radius $r = f(x_i)$ has the area $A = \pi r^2$, which is just the area of the slice of the revolution body at $x = x_i$.
- Using a finite but small cylinder with height Δx, we obtain that it has the volume $V = \pi r^2 \Delta x$.
- The volume of the revolution body can then be approximated by the sum of the volumes of the n cylinders of varying radius using the formula $\sum_{i=1}^{n} \pi f(x_i)^2 \Delta x$.
- In the limit process $n \to \infty$ (or similarly, when $\Delta x \to 0$), this Riemann sum becomes the well-known integral $\int_a^b \pi f(x)^2 dx$.

[1] https://www.youtube.com/watch?v=SYGLhIKoDc8
[2] https://github.com/FlorianSchneiderIU/Manim-math/blob/main/scripts/rotationskoerper.py

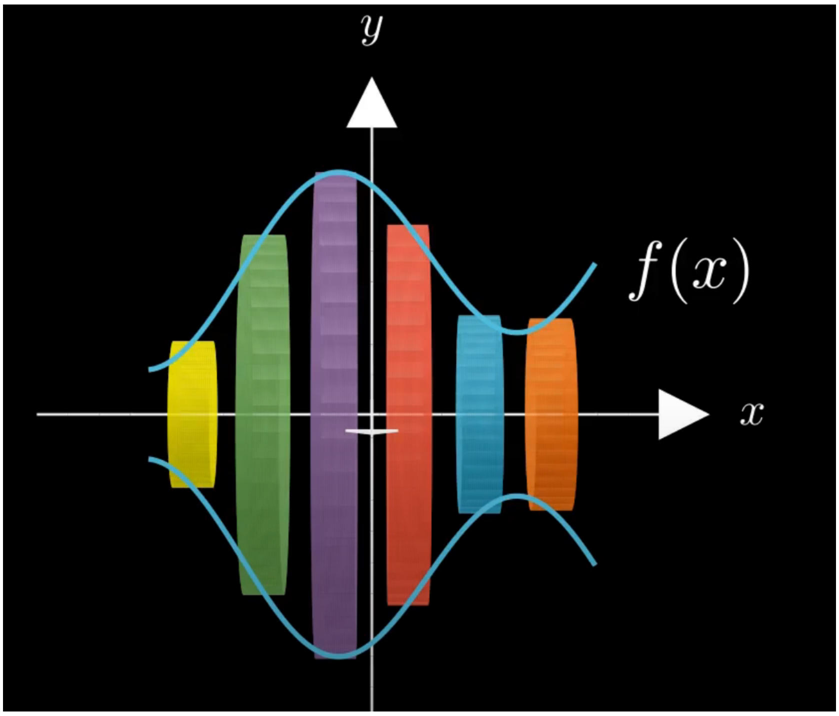


Figure 2: Splitting the revolution body into several small torus slices (Taken from https://www.youtube.com/watch?v=SYGLhIKoDc8).

This explanation workflow uses the simple paradigm to go from the easy and known facts (the circle area, operations of discrete mathematics) to the potentially abstract and complex facts (e.g. the integral volume formula). While the process is easy to follow on paper, visualizing this turns out to be rather difficult.

One problem is that different steps happen in different planes (related to the 3D object). The biggest problem in Manim here is that any rotation of the camera by default rotates text elements like axis labels, titles and so on alike, leaving the user with a zero-width rotated text which are unreadable. Certainly, there are options available to place texts outside of the coordinate system, but keeping the label (for example the one at the x axis tip) at the right position during the rotation is highly non-trivial.

For simplicity, since most of the animation happens in the x-y plane, we start in the x-z plane (90 ° rotation around the y-axis) using the command:

```
self.set_camera_orientation(phi=-90 * DEGREES, theta=0, gamma=90 * DEGREES)
```

The command was introduced by the author by analogy to content that ChatGPT created at other failing places. Originally, ChatGPT wanted to start in the normal x-y plane and then perform the rest in the x-z plane, causing the whole simulation to be messed up totally because of the lack of understanding in which rotation axis the frame currently lives.

This is, where we also plot the circle to demonstrate the area formula. When moving back to the x-y plane, we fix the orientation by simultaneously rotating the camera, static objects and all the labels alike.

3.2 MANAGING RENDER TIME AND QUALITY

Another problem was the runtime when rendering the video. Particularly in 3D, it can take a while until a scene is ready. For example, one intermediate run of this video on full quality (before some code optimizations) took roughly 4 hours on a normal laptop. We therefore introduced a quality flag that adjusted the main features (like resolution of the torus, number of rotation frames, ...). This enabled us to test and develop the script.

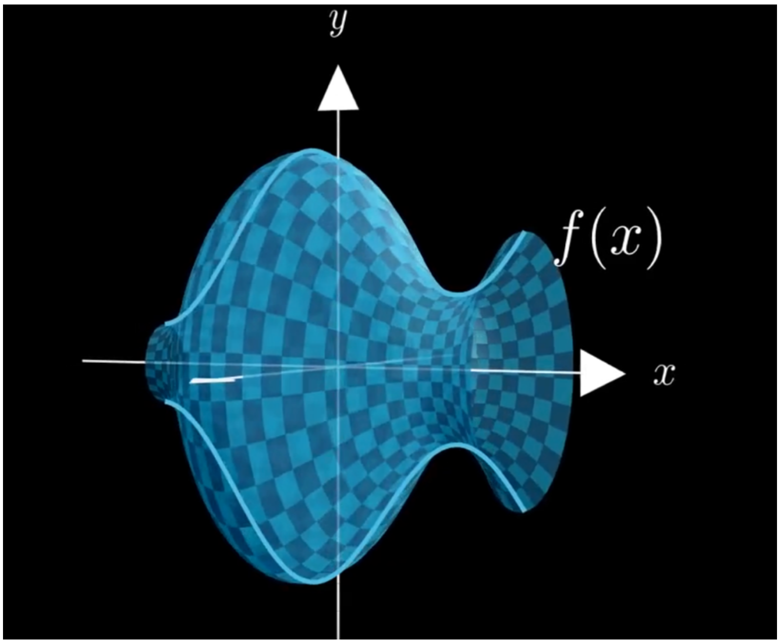


Figure 3: A solid of revolution in its frame.

4 Development processes of Manim videos using large language models

Manim has a lot of pitfalls that can slow down the development process. In the following, we would like to discuss some of the tools and concepts that we found useful to speed up this process while maintaining structural integrity of the scripts.

The obvious and naïve first choice would be to take an AI coding assistant to support us. AI tools can assist in coding in various way and have proven to be able to program python code (Chen et al., 2021; Peng et al., 2023; Rozière et al., 2024). Assistants can come in various way, like openAI ChatGPT o3 in the default chat interface or openAI Codex/GitHub Spark/GitHub CoPilot that can directly interact with a git-hosted code base. Note though, that recent studies discuss this controversially, showing that for skilled developers, AI can significantly decrease the productivity while subjectively giving the feeling of being quicker in task completion (Becker et al., 2025). However, we are especially looking at this from the perspective of a novice in Manim (any maybe even python), relativizing this result.

4.1 VERSIONS OF MANIM: IMPLICATIONS FOR PROMPTING

The first thing we have to realize is that there are two variants of Manim out there. The first one is the original Manim package created by 3b1b (ManimGL). The second one is the Manim community edition (ManimCE). The latter is much more active in the development and recommended for most users (*ManimGL vs ManimCE*, n.d.). Unfortunately, the two repositories started deviating strongly and most AI assistants mix up the syntax of them. Our first best practice is thus the following:

When prompting an AI assistant, specifically name that you are working with ManimCE and which version you are using.

4.2 STRENGTHS AND LIMITS OF AI CODING ASSISTANTS

- Another issue with Chat Assistants (e.g., ChatGPT o3 via the web interface) is that, depending on their type, context window etc tend to oversimplify code after several stages. Sometimes, working with a canvas can help, but developing long code for scenes tends to be fragile. In the end, you often get code that states something like "… rest of your code" or similar. Worse, the new (stated as) "copy and go" code in the later run removed some important functionality.
- API assistants (incorporated, e.g., in Github Copilot) tend to break the file syntax in more complicated scenarios. When using the edit mode, the final code might be fully unusable.

While Chat Assistants turn out to be great in creating a first draft of the scene (more on that in Section 4), we do not recommend to use them for continuous code development. While in some cases they might be superior to the other assistant methods (in particular due to their web search capabilities), this is only relevant for very special cases.

4.3 A GIT-BASED AGENTIC WORKFLOW FOR MANIM DEVELOPMENT

Our suggestion is to use a Git-based agentic workflow[1] [2]. The most important part is the following:

Develop your scene step by step and create a Git commit whenever a part of your scene/storyboad is working.

In particular, when using Github Copilot (for example in VS Code), staging/committing after every modification of the AI assistant/agents turns out to be crucial to not lose working progress. We observed the best workflow using OpenAI Codex, which creates Git commits and pull requests on its own. Our recommendation for a quick idea-to-product workflow is the following:

[1] Git is a version control system that allows you to track changes and backup your code. It saves snapshots of your project over time so you can see what changed, undo mistakes, and safely try ideas in separate "branches" without breaking the main version.
[2] Agentic LLMs are AI assistants that don't just predict the next word – they can plan small sequences of actions toward a goal, use tools (like search, linters, or test runners), and adjust based on results. They can explain code, propose changes, write tests, refactor files, and iterate in a loop – while keeping you in control to review and approve each step.

1. Create a storyboard sketching the video with a reasoning AI of your choice (ChatGPT o3, Claude 4, Gemini 2.5, DeepSeek, …). Let it break down the video into as little steps as possible.
2. Adjust the storyboard manually to your needs.
3. Optional: Try to generate the full scene once within the same model or any agentic model using the above storyboard. In most cases, this step will fail, but if it works it will be an immense time win.
4. Go scene by scene (or even smaller) and create the video using Codex or Github Copilot Agents/Spark.
5. Build every code increment and stage or commit the changes to your Git repository to maintain code integrity.

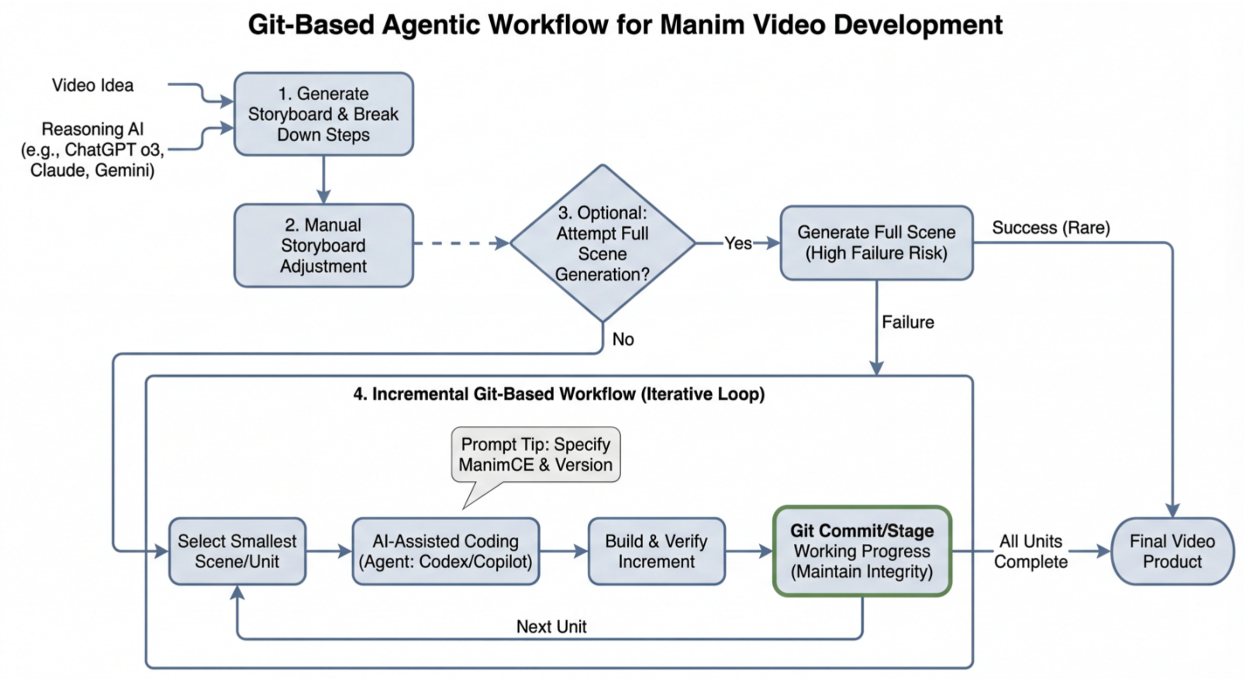


Figure 4: Git-Based Agentic Workflow for Manim Video Development

5 Curiosity-infused storyboarding of mathematical videos

5.1 CURIOSITY AS A DRIVER OF MATHEMATICAL LEARNING

Having described the experiments we ran, we return to the central initial objective of creating videos: The first step is the writing of a storyboard based on which the video will be created through programming. We wish to provide students with the necessary elements to instill mathematical curiosity into our videos.

ChatGPT provides the following examples that can help incorporate such elements in our videos:

- “Asking Why and What If”
- “Why does this formula work?”
- “What if we changed this number—would the pattern still hold?”
- “Why are triangular numbers shaped that way?”

- “Why do even numbers behave like this in division?”

We could also add the following examples to that list:

- “Wondering About Patterns”
- “Explore variations of a problem.”

As discussed in section 2, research shows that curiosity is linked to better problem-solving skills, increased persistence, deeper conceptual understanding and positive beliefs about mathematics.

Engel argues that curiosity is a driving force behind deep engagement and learning. Students who exhibit curiosity tend to explore problems more deeply, persist longer in the face of difficulty, and develop stronger conceptual understanding (Engel, 2013).

Ingredients such as prompts and their possible immediate responses which are most likely wrong can trigger reflection and challenge or defy our intuition. In addition, such ingredients can not only assist in instilling curiosity, but also can also stimulate further reflection: “Why was my first attempt wrong?” Answering this question allows for deeper learning and understanding.

An introduction to the video should have the effect of a good trailer, motivating students to go through the video with curiosity and enthusiasm with no further effort than the mere desire to find out what the video is about and an emotional feeling that it is worth watching it to satisfy our own curiosity.

The idea that a good video should last at most five minutes is already acknowledging that the video is boring enough and not engaging, and that therefore students can only endure five minutes of it. Besides, unfortunately, almost any good description of a complex mathematical problem along with the explanation of the concepts involved requires much more than five minutes. Storyboarding videos is a quest to keep equilibrium between capturing attention, motivating and being understandable.

5.2 STORYBOARD INGREDIENTS FOR CURIOSITY-INFUSED VIDEOS

In this context, we wish to highlight and list important aspects that are thought to be relevant when designing the story telling of a video. These aspects can be part of a prompt to a chat bot:

- Instill math's curiosity. This can be done by incorporating reflective questions before providing any answer. E.g.
    - Why cannot the ratio between the cathetus and the hypotenuse be greater than 1? How could we prove it?
    - Why does the definition of the Euler’s function Phi(n) include n if n is never coprime with itself?
    - Why “Prime numbers are numbers divisible only by 1 and themselves” is not a good definition but more a description of primes.
- Make these questions such that they defy system1 and activate system 2. After all, curiosity is nothing but the need to find an explanation for the unexpected.
- Another strategy is to post something that is incorrect and clashes with reality or with a fundamental axiom. Encourage students to find the inconsistence, the flaw in the procedure/assumptions, and reasoning.

- Instill awareness about system 1 and 2. by adding a request to explore first the fast-thinking process then activate the slow thinking to be vigilant. Explicitly identifying the processes as 1 and 2 may help. E.g. Asking the question of "Which of the two approaches cools the coffee faster? Adding the milk and waiting 10 minutes or waiting 10 minutes and adding the milk?"
- Math is built on earlier concepts/prerequisites: including recommendations of previous videos to ensure that students have all previous concepts can be helpful. E.g., "If you don't know this, you may watch this video and come back".
- Provide choices for further or previous videos so that students can take agency over their learning experience.
- Build solid foundational concepts, e.g. use of deductive reasoning rather than memory or pattern recognition. Test this deductive reasoning by instilling reflection and asking why?
- Instill awareness that gaps have a cascading effect on later performance. Suggest videos, e.g., if you do not know where this property comes from, check out this other video.
- Make sure to take the time to build solid conceptual foundations before they move on.
- Diagnostics. Encourage students to stop and solve simple problems that assist them in testing their understanding.
- Encourage students to reflect on incorrect procedures, e.g., "Why was the procedure incorrect? What was the flaw in deductive reasoning?"
- Check for foundational misunderstandings.
- Use of logic and deductive reasoning rather than memory to follow procedures (activation of system 2). Encourage anticipation of the result, e.g., give students the possibility to pause the video and deduce the answer independently.
- Acknowledge of the limitations of system 1.
- Cooperation of system 1 and 2 when needed, e.g., quick use of properties which were already proved and well understood.
- Interconnectivity of videos to review or connect concepts and ideas. Ensure that nothing is "simply memorized".
- Avoid prior-task failure effects. E.g., at first, problems should be always simple and almost trivial to encourage active participation. The level of problems should increase progressively.
- Raise awareness over the importance of motivation. E.g., if something is too difficult, avoid it, tackle a less complex problem. Preserve motivation as the students' most valuable treasure.
- A video that demotivates students is worse than no video.
- Encourage a set of positive math beliefs, e.g., practice makes progress, and the sky is the limit, that is with practice and effort there is no limit to our progress.
- Provide a wrong fact in the video and let students guess what the correct answer is.

6 Consuming Learning Videos in Service Lectures

Learning videos have a broad consumption potential which we try to classify here. Being broadly accessible on the web and from any device, different patterns apply.

The first characteristic of consumption is the context of use: In the guided case, students observe the professor presenting the videos or some of its part. The free pause and play rhythm as well as the possibility to show particular places with the hands all contribute to the support the learning (e.g. as explained in (Cook et al., 2008) or in (Mayer, 2009). The guided use of a video can be done in synchronous online and in presence learning.

In this case, videos do not necessarily require precise timing or a voice-over. The teacher can easily pause, rewind, highlight any information, or add extra verbal or visual input. This allows for comparably simple requirements for the video itself.

An alternative context is the self-guided usage of the video which is, typically, linked directly from the learning management webpage. Employing the videos as a way to learn before the course is one of the cornerstones of flipped-classrooms (Lage et al., 2000), a modern method where the learners meet in class in order to achieve tasks and ask questions about them. Self-guided consumption is generally performed alone but could be enjoyed in small student groups and can support a discussion which enriches and stabilizes the learning. It is also self-paced, and this difference is crucial: Even though the composed videos are short and can request a lot of cognitive resources in single instants, they can be paused and rewound at will. This supports asking oneself questions and verifying their answers in the videos. This is effective when the videos are consumed in places where learning with coursebooks or large papers are not so practical, for example when standing in the commuter-trains or when walking. While self-guided consumption appears to be infinitely scalable, a consumption within in-presence courses with limited-size classes (< 20 students) can also become an effective carrier of personal interactions.

These videos require much more care during story board and content creation. In particular, voice overs need to exactly match the Manim video scenes. This makes the video creation process much more difficult as the timing needs to be exact, potentially causing more adaptations and re-renders of the Manim video itself.

Finally, an important difference is the view size of the consumption: employing small devices and having readable images implies including very few characters on the video. The creator of the videos must be aware of this and decide on accepting or including the limited view sizes. Similarly, students may decide whether it is appropriate or not (e.g. if they only want to be reminded without reading in detail).

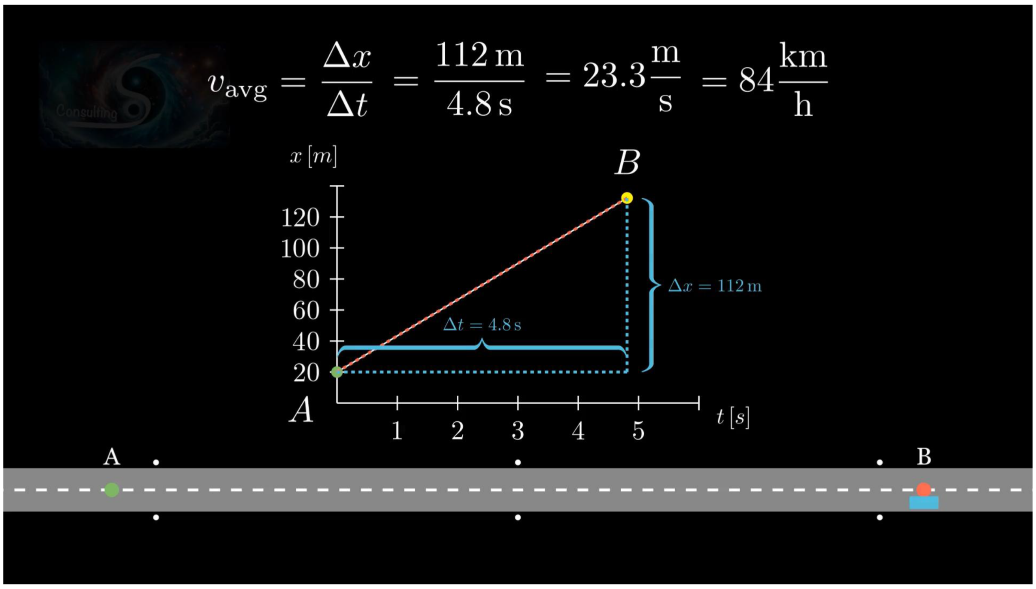
7 A practical Evaluation

We implemented a series of Manim videos for the dual studies lecture “Mathematics: Analysis” in the study program “Civil engineering” of the IU International University of Applied Sciences in the summer semester 2025. The videos can be separated into two categories: *1) Practical applications* and 2) *Explanation of abstract mathematical contexts*.

All the videos created were uploaded on YouTube[1] with the corresponding link embedded in the lecture presentation.

[1] https://www.youtube.com/playlist?list=PLmMvXdEfSSwJSrbUCx5ioO0SnVgKsrHsU

ANWENDUNGSBEISPIEL: GESCHWINDIGKEITSMESSUNG GLEICHFÖRMIGE BEWEGUNG



Quelle: Florian Schneider (IU, 2025, https://youtu.be/W7JQgf7Teh8)

Figure 5: Usage of a video in the Powerpoint slides of DSBBAUMA01 - Analysis

This allows for students to rewatch the videos on demand both in the preparation of classes and during the learning phase for exams.

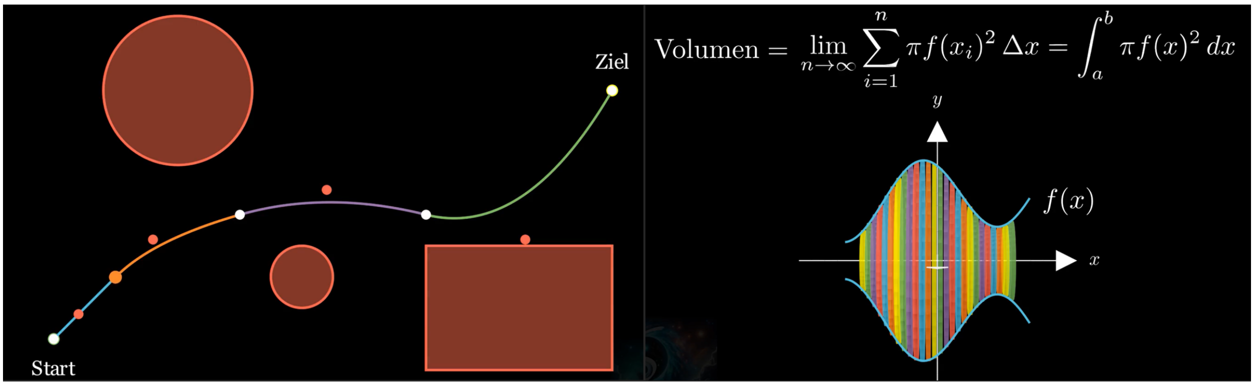


Figure 6: Left: Application of piece-wise quadratic functions in motion planning (category 1)). Right: Visualization of the limit process to derive the volume formula for a solid of revolution (category 2)).

As an application constructing the videos, we used them in a course of 12 students. We distributed a survey after the course. It was complimentary to the (regular) course evaluation. Even though not statistically relevant, we analyzed this mini survey where 6 students provided qualitative and quantitative feedback to identify if the videos had a subjectively positive impact on the students' learning experience. All quantitative questions were set on a Likert scale from 1 (no consent) to 5 (full consent).

Such a small size, and the fact that it is about a single course and a single teacher, make for a rather small generalizability of these statistics. Moreover, it has been done only in the context of students in dual-study-branches, where presence at the University alternates with working situations. This implies a very different relationship to the learning media than other forms of studies (e.g. distant studies) where videos are the most important learning opportunity; this also makes the videos more quickly insertable in lectures.

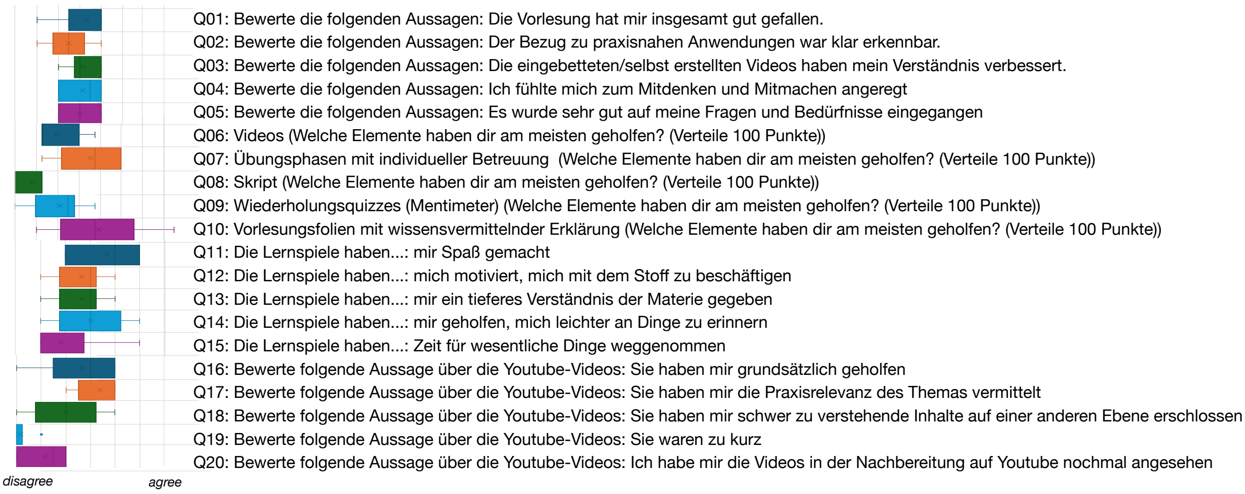


Fig 6: Student answers to the quantitative questions relating to the videos in the class "Mathematics: Analysis". The diagrams are scaled with left: full disagreement and right: full agreement. Colors are not relevant.

The relevant statistical parameters for the five questions' score are:

Question	Mean	Median	Mode	StDev	Kurtosis	Min	Max	Skewness
1	3,670	4,0	4	1,506	1,531	1	5	-1,27
2	4,400	5,0	5	0,894	0,313	3	5	-1,26
3	3,000	3,0	3	1,414	-0,300	1	5	0,00
4	1,167	1,0	1	0,408	6,000	1	2	2,45
5	2,167	2,5	3	0,983	-2,390	1	3	-0,46

Moreover, we observed the statistics of the video consumption, as offered by the YouTube channel:

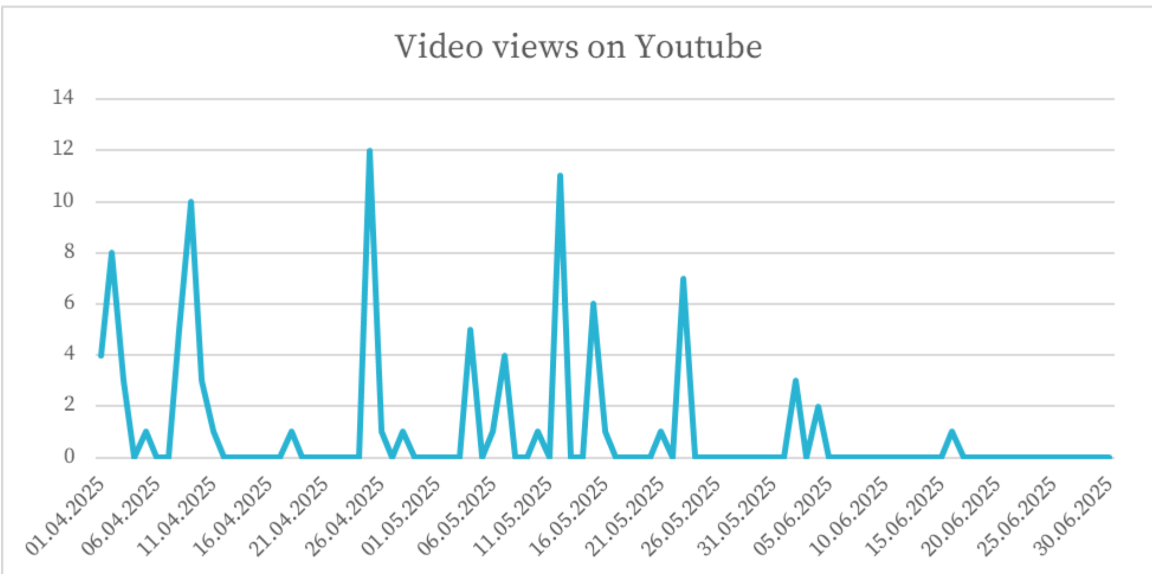


Figure 7: Video views on YouTube

During the lecture period (Start: 01.04.2025, exam on 06.06.2025), videos are watched mostly when they were released. That means, student engagement with the videos is highest close to the corresponding lecture. During the exam phase, no further spikes are visible. This implies that students do not use the videos for exam preparation but for deepening their understanding during the lecture itself.

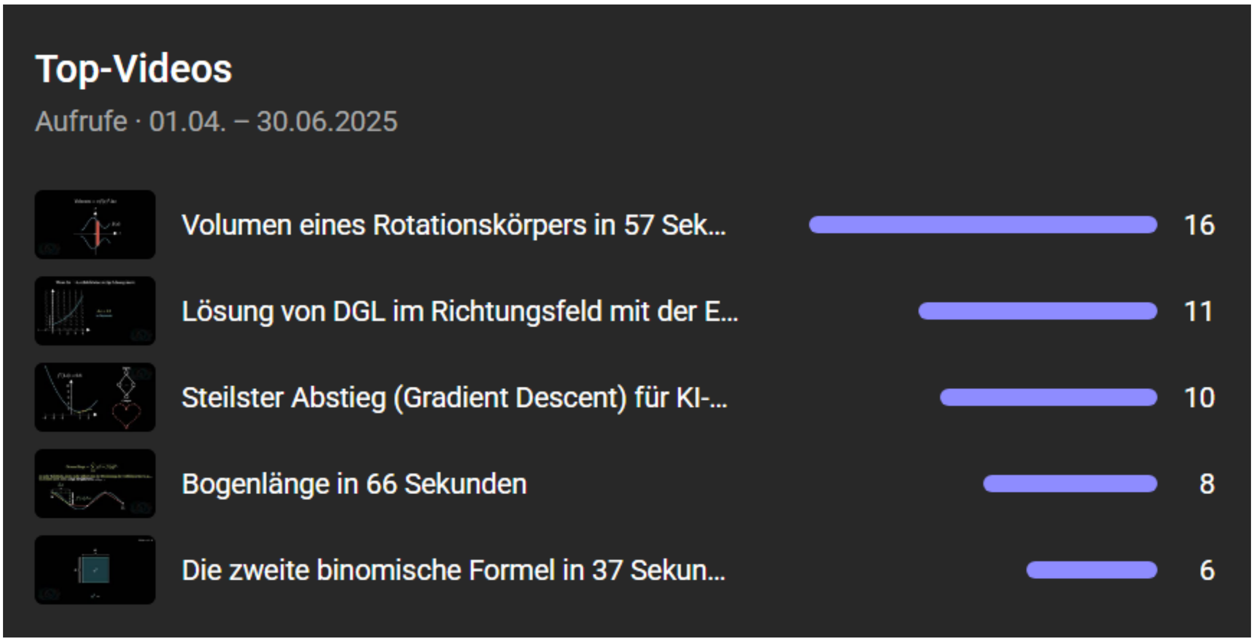


Figure 8: Videos with the most views are also the ones with the highest mathematical complexity.

Regarding the qualitative question, how the videos helped the students concretely, only a few sentences were answered[1]:

- Good visualization of abstract concepts
- They have often answered the question “Why do you need this at all” and given the formulas a “use”
- The videos have created a better visual understanding of the topic we are currently working on.

The only missing thing that one student complained about was the missing link to the examples. This suggests that further embedding in the lecture context would be helpful.

8 Discussion

8.1 PRODUCTION EFFORT AND REUSABILITY

We have presented an approach to embark on the regular production and use of videos in the classroom to demonstrate mathematical knowledge. While the production process has cost a considerable amount of time, we have highlighted several advantages to support a deep understanding of mathematics. The fact that these videos can be reused and adapted for future teaching makes

[1] The German answers have been translated using DeepL after minor corrections by the author.

production overhead tolerable. Similarly, the fact that chat-bots can strongly support the generation of the source code for Manim videos makes the embarkment and learning process effective and goal-oriented. Depending on the complexity and length of a video, the average creation time was roughly in the range of 30 to 300 minutes per minute of the video - including "non-supervised" render time and AI reasoning time that can be potentially used for exam corrections or other short tasks.

8.2 MANIM VIDEOS AS REUSABLE OPEN RESOURCES

The Manim coding format, which includes the entire video instructions, is economic in many respects: It can be shared by versioning repositories, and it can be stored in a lightweight storage (a few kilobytes) and, thereafter, generate the megabytes of videos necessary for it to be working. The source-code nature even invites for further enrichments thus stimulating re-use which is limited in the video nature (Baas & Schuwer, 2020). It can thus support a broad Open Educational Resources (OER) sharing economy.

The competency of realizing videos is deeply rooted in the media culture of teaching professionals at the IU International University of Applied Science whose activity includes a large series of programs in distance learning for which asynchronous videos professionally edited are central objects to learning. Nonetheless, mathematics animation videos are not common practice, and we contend that the IU will make the competency of developing such videos part of a relevant teaching certificate that could be acquired by the teaching personnel.

8.3 POSITIONING MANIM ANIMATIONS AMONG OTHER LEARNING MEDIA

Our presentation has situated the mathematics phenomena videos as hybrid objects between different objects of mathematical learning:

- They share aspects of canned teaching videos (e.g. those of the Khan Academy) but are shorter, without voice, and are more simulation oriented. They, thus, leave more space for the learner to pause, reflect, and reproduce for themselves.
- They share aspects of dynamic geometry such as those implemented by Cabri[1] or GeoGebra[2] with the possibility to adjust the playback (pause, rewind, speed-up), but the videos lack the variation principle (Leung et al., 2013). In this sense, they are simpler to manipulate and easier to consume on the go on mobile devices.
- They share aspects of the notebooks' sharing practice where a mathematical reasoning is shared as a file (Jupyter Notebook, Observable HQ, …) which can be re-executed possibly adapted. The unravelling process is similar, but notebooks are not aimed at presenting an evolving visualization and require more technical installations. Moreover, interactive workbooks tend to have code that is inappropriate for teaching purposes.
- They share aspects of blackboard teaching sessions where content is progressively built up and where the important aspects of the animations are highlighted resembling the hands of the teacher

[1] Cabri is a family of dynamic geometry software products which pioneered dynamic geometry. See https://cabri.com .

[2] GeoGebra is a set of open-source products for performing algebra-near products, among which one for dynamic geometry. See https://geogebra.org .

(Kersey et al., 2024). Through their simplicity, they can easily (and without much contradiction) be used in a course. Watching the videos again serves as an excellent memory cue, reminding learners of the material taught.

Our report, however, shows limitations by its size (the number of videos produced and the number of respondents in the survey) and, more importantly, by its lack of connecting the use to measurable learning gains through, for example, exams.

9 Future Work

In future work, we wish to use a mixed-methods framework to rigorously evaluate the pedagogical impact of interactive digital materials. The study will incorporate both quantitative and qualitative data collection, utilizing pre- and post-intervention assessments to measure learning outcomes, user engagement, and the cultivation of higher order thinking skills. Data sources will include standardized tests, analytic tracking of user interaction, and structured interviews or surveys to capture nuanced learner experiences.

Systematic A-B testing can be integrated to assess the specific influence of curiosity-driven teaser videos compared to control conditions without introductory stimuli. Randomized controlled trial design can be used to evaluate differences in learner motivation, initial engagement metrics, and knowledge retention over time, allowing for robust statistical analysis of intervention effects on both short-term and sustained learning.

Further aspects of the learning may be considered when creating videos which are assemblies of graphical representations. The choice of color may end up being a problem for some students (who may confuse them). In addition, some students may need even bigger characters which is only partially doable well in videos. Finally, it remains unclear whether the graphics of the videos displayed on some tactile screens can be usable or if adjustments will be needed to make it suitable for visually impaired persons (e.g. by reading-aloud the formulas with another voice than the teacher or adding further descriptions).

In distance learning, it would be productive to also focus on embedding Manim-like WebGL exports directly into the Moodle learning management system. This approach will ensure that interactive, manipulable visualizations are accessible in-browser, preventing the need for additional software installation and thereby increasing accessibility for all learner populations. These visual tools will be designed to accommodate multiple learning pathways and foster real-time exploration of complex concepts.

To facilitate open science and scalability, a curated repository of shareable scenes could be established. All resources will be licensed under Creative Commons CC-BY to guarantee transparency, reproducibility, and ease of adoption by other educators and institutions. The repository should be structured for collaborative development, encouraging contributions, and iterative improvements from the educational community.

Additionally, the research will examine the effectiveness of explorative branching videos, delivered via QR-based, choose-your-own-path frameworks, as a hybrid instructional model. Analysis will focus on the potential of these tools to personalize learning trajectories, enhance learner agency, and support a range of cognitive preferences and learning strategies. Efficacy will be measured through both engagement analytics and qualitative feedback from participants.

10 Conclusion

In this discussion paper, we have examined the pedagogical value and production workflow of short, animated Manim-based videos for mathematics teaching, with a particular focus on service lectures in distance and dual study programs. We addressed the interplay between intuitive (System 1) and reflective (System 2) cognitive processes in mathematical learning and discussed how thoughtfully designed videos – especially those that foster curiosity and critical reflection – can activate deeper engagement and more robust conceptual understanding.

Our workflow analysis highlighted both the opportunities and challenges in producing Manim videos, especially when leveraging large language models and AI coding assistants. While the initial learning curve and technical hurdles are significant, the capacity to reuse and adapt video materials across semesters and courses helps amortize the production effort. Furthermore, we outlined practical guidelines for integrating curiosity-driven storyboarding and self-regulated learning strategies into video design, aiming to counteract limiting mathematical beliefs and foster a growth mindset among learners.

A small-scale evaluation with students indicates that such videos can enhance conceptual clarity, increase motivation, and facilitate independent study, though further research is needed to assess long-term learning outcomes and broader scalability. The practical experiences reported here, combined with initial student feedback, suggest that Manim-based videos hold promise as a versatile and reusable tool for mathematics education, particularly in contexts where abstract concepts must be visualized dynamically.

We encourage mathematics educators – especially those teaching large, heterogeneous service courses – to consider piloting short, animated videos in their curricula. As digital technologies and AI tools continue to evolve, we anticipate that video-based, curiosity-infused instructional materials will become an increasingly central element of effective and inclusive mathematics teaching. Future work should expand the empirical evidence base, explore A/B testing of curiosity teasers, and develop open repositories of shareable, editable video resources for the broader educational community.

AI Disclaimer

In our efforts to ensure high-quality content and innovative solutions, we leverage generative artificial intelligence (AI) technologies as well as other AI technologies. These tools assist us in improving text flow, co-creating the Manim source code for our animations, and generating source code for images. While AI significantly enhances our productivity and creativity, we remain dedicated to human oversight and careful review of all AI contributions to maintain accuracy and integrity in our work.

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