Narrative-Driven Learning: Teaching Finite State Machines Through Storytelling

Bogdan Iudean[a] and Andreea Vescan[b]

Computer Science Department, Faculty of Mathematics and Computer Science, Babeş-Bolyai University, Cluj-Napoca, Romania

{bogdan.iudean, andreea.vescan}@ubbcluj.ro

Keywords: Finite State Machine, Storytelling, Teaching, Learning.

Abstract: Teaching embedding systems demands a thorough understanding of computation models, with Finite State Machines (FSM) serving as one of the frameworks for developing the intricate behaviors of these systems. This study investigates the effectiveness of teaching Finite State Machines through storytelling using a controlled experiment with two groups: a Control Group (CG) taught traditionally and a Storytelling Group (SG) taught using a narrative-driven video. Data from pre-tests and post-tests and feedback questionnaires reveal that while storytelling did not significantly improve post-test scores, it enhanced application skills in the SG group. Storytelling helped students better connect FSM concepts to real-life scenarios like traffic lights and vending machines, while CG responses remained more abstract. Additionally, SG participants rated the video highly for attention and clarity, though some preferred more direct explanations. These findings suggest storytelling supports conceptual understanding and engagement, offering a complementary approach to teaching FSMs.

1 INTRODUCTION

Finite State Machines (FSMs) are fundamental to understanding computational models in embedded systems, offering a structured approach for modeling systems with discrete states and well-defined transitions based on inputs. FSMs, defined as “conceptual machines capable of existing in one of a finite number of states at any given time” (Lee and Yannakakis, 1996), are extensively used across disciplines, from engineering and computer science to control systems and natural language processing (Karttunen, 2000). The FSM concept has evolved as a core framework for system modeling, simplifying the representation of complex behaviors and operations that characterize many embedded systems (Radojevic and Salcic, 2011). Despite their significance, FSMs often present learning challenges for students due to their abstract nature and the requirement to think in discrete, sequential steps (Henry et al., 2022).

Storytelling as a Teaching Strategy for Complex Concepts. Educational research increasingly emphasizes the power of storytelling in conveying complex, technical concepts (Wu and Chen, 2020). Storytelling leverages the human affinity for narratives to provide context, create emotional connections, and improve retention, making it especially effective in STEM education where abstract concepts can be challenging to grasp (Collins et al., 2023; Angel-Fernandez and Vincze, 2018). Through storytelling, complex computational models can be presented in a more engaging, memorable format. Studies (Heymann and Greeff, 2018; Parham-Mocello et al., 2019; Resnyansky, 2020; Min et al., 2020) indicate that narrative-driven instruction can enhance cognitive processing by allowing learners to form mental models based on familiar narrative patterns, which in turn supports better conceptual understanding. This approach is supported by theories of situated learning, which suggest that knowledge is best understood when contextualized in realistic scenarios (Segel and Heer, 2010).

Our study builds on these insights by exploring the potential of storytelling, specifically through animated video, as a method to teach FSM concepts in a graduate-level computational models course. The video used in this study tells the imaginative story of a prehistoric man, Buga, who attempts to tame a mammoth using an FSM to understand its behavior. By embedding FSM principles into a narrative structure, we aimed to make FSM concepts more approachable and relatable for students. Story-based ap-

[a] https://orcid.org/0000-0001-6233-3570
[b] https://orcid.org/0000-0002-9049-5726

Iudean, B. and Vescan, A.
Narrative-Driven Learning: Teaching Finite State Machines Through Storytelling.
DOI: 10.5220/0013471600003932

In *Proceedings of the 17th International Conference on Computer Supported Education (CSEDU 2025) - Volume 2*, pages 627-638
ISBN: 978-989-758-746-7; ISSN: 2184-5026

proaches have shown promise in promoting engagement and improving learning outcomes in the previously mentioned STEM fields (Collins et al., 2023; Angel-Fernandez and Vincze, 2018), suggesting that they may similarly benefit students studying computational models for embedded systems.

The aim of the study is to evaluate the effectiveness of using visual storytelling as a teaching method within a take-home assignment activity for using finite state machines (FSMs) in a university-level course. One group of students was given access to the educational video along the traditional learning materials, while another group received only traditional instructional material without the video. The study seeks to determine whether the storytelling approach enhances students' understanding, academic performance, and engagement compared to conventional teaching techniques.

The research investigation is formulated under the following three research questions, with the findings being articulated.

- *RQ1: Are there measurable differences in learning outcomes between students who engaged with the storytelling video content and those who followed traditional instructions?* Answer: *The difference, did not reveal a better performance for the storytelling group, however, qualitative results showed better results regarding the application skills.*
- *RQ2: Does storytelling video content improve students' understanding of FSMs compared to conventional instructional approaches?* Answer: *The storytelling group answers reveal a deeper understanding of FSM concepts; we based our answer on results of the qualitative analysis.*
- *RQ3: How does the storytelling video content approach impact student engagement and perception of learning FSMs?* Answer: *The storytelling group revealed more enthusiasm towards the subject; we based our answer on the results of the qualitative analysis.*

The research methodology consisted of a controlled experiment using two student groups, one taught FSMs through a storytelling video and the other through traditional instruction. Using both qualitative and quantitative analysis, data on student performance and engagement were collected through assessments, questionnaires, and observational feedback.

This study's findings will contribute to a growing body of research on innovative instructional strategies in computational and engineering education. By investigating storytelling's impact on FSM comprehension, this research may inform future approaches for teaching complex systems and computational models, ultimately enhancing educational practices in technical disciplines.

The contributions of this research are:

- **A Novel Pedagogical Approach for Teaching FSM Concepts.** This study introduces a prototype multimedia storytelling-based method for teaching abstract technical concepts in an engaging way.
- **Evaluation Through Multi-Stage Questionnaires and Hands-on Tasks.** The effectiveness of the storytelling approach was evaluated using a mix of qualitative and quantitative analysis that used pre-tests and post-tests.

The rest of the paper is organized as follows: Section 2 covers FSM education, the use of storytelling, and instructional design with media. Section 3 details the research methodology with instructional information and corresponding teaching artifacts. In Section 4, the results are presented with quantitative and qualitative analysis. Section 5 discusses the results of our study, highlighting key findings, while Section 6 explores the broader implications, recommendations for educators, and future research directions. Finally, Section 7 raises the threats to validity, and Section 8 concludes the study.

2 RELATED WORK

Next, related work is reviewed regarding FSM education, storytelling, and media-based design, emphasizing storytelling's role in contextualizing concepts and media's ability to simplify complex topics visually.

2.1 FSM Education and Learning Strategies

FSMs are commonly used in engineering and computational sciences to model systems with distinct states and transitions. However, traditional teaching methods (Joseph et al., 2013) often rely on abstract, mathematical instruction, which can be difficult for students to grasp and lacks engagement (Dekeyser and Aljendi, 2015). Innovative approaches, such as interactive platforms and augmented reality, have shown promise in making FSM learning more practical and engaging (Nadeem et al., 2022; Dengel, 2018). Building on these strategies, our study introduces a narrative-based video where a prehistoric man models a mammoth's behavior using FSM concepts to help students connect theory with real-world applications.

2.2 Use of Storytelling in Education

Storytelling (Barchas-Lichtenstein et al., ; Landrum et al., 2019) is a powerful tool in STEM education, helping students understand complex ideas by embedding abstract concepts in relatable narratives (Barchas-Lichtenstein et al., 2023). This approach fosters emotional connection, which enhances engagement and retention, particularly for abstract computational topics (Groshans et al., 2019). Research shows that storytelling bridges cognitive gaps by contextualizing information, making STEM subjects more accessible (Mou, 2024). Digital storytelling further enriches learning by combining audio-visual elements with narrative structures (Dochshanov and Tramonti, 2022). *Our study builds on this research by using structured storytelling elements (Durak, 2018)—such as narrative, setting, and plot—to create an engaging framework specifically for teaching FSMs.*

2.3 Media and Animation in Instructional Design

The use of media and animation in education has become popular, especially for technical subjects where visual aids enhance understanding. Animations help simplify complex topics like FSM states and transitions (Dengel, 2018) by breaking them into digestible visual segments (Berreth et al., 2020; Hill and Grinnell, 2014). Media-rich content creates dynamic, interactive learning environments that foster engagement and support long-term retention (Bravo et al., 2021). *Our study adopts this approach by using vivid animations, characters, and a visual narrative, along with an on-screen instructor who narrates and uses gestures to reinforce FSM concepts.*

3 METHODOLOGY

This section details the research methodology used to evaluate the effectiveness of storytelling-driven video in teaching Finite State Machine concept. The methodology includes defining the research question, describing the teaching materials and content, and explaining the data collection process through questionnaires. A controlled experiments is employed using two groups of students: CG (Control Group) and SG (Storytelling Group). A mixed method research is used to analyze the collected data, both quantitative and qualitative analysis.

3.1 Course and Participants

The study involved two groups of graduate students enrolled in the "Computational Models for Embedded Systems" course at *[University Anonymous for review]*. In total, 33 students participated into the study, students being divided into two groups: Group CG (control group, 16 students) and Group S (storytelling group, 17 students). The two groups were formed randomly; all students first enrolled in the activity and the researchers assigned to each group the enrolled students in a random way. CG group received traditional instruction in FSM design, while SG group engaged with a storytelling-driven video teaching FSM concepts through a prehistoric storyline. More information on the activity is provided in Section 3.4, outlining the teaching method within a take-home assignment activity. All participants gave informed consent prior to participation, and the study complied with ethical guidelines for research by [University Anonymous for review].

3.2 Objectives and Research Questions

The primary objective of this study is to assess whether storytelling in video form could improve comprehension of FSM concepts among graduate students compared to traditional instructional methods. We aim to answer the following research questions:

> *RQ1: Are there measurable differences in learning outcomes between students who engaged with the storytelling video content and those who followed traditional instructions?*

> *RQ2: Does storytelling video content improve students' understanding of FSMs compared to conventional instructional approaches?*

> *RQ3: How does the storytelling video approach impact student engagement and perception of learning FSMs?*

3.3 Teaching Materials and Content

The primary teaching material for Group SG was a 10-minute animated video titled "Buga and the Mammoth: A Finite State Machine Story", designed to introduce FSM concepts through a storyline of a prehistoric character, Buga, who attempts to tame a mammoth by modeling its behavior with FSMs. The video used animations to visually represent the FSM states and transitions, aiming to simplify abstract concepts by contextualizing them in a relatable scenario. CG group, in contrast, was provided with conventional written materials and diagrams describing FSM theory and application.

3.3.1 Overview of Video Content and Storyline

The instructional video, titled “Buga and the Mammoth: A Finite State Machine Story“, uses a narrative-based approach to introduce FSM concepts in an engaging way. The story follows Buga, a prehistoric character, as he tames a mammoth by modeling its behavior using FSM principles. The mammoth’s behavioral states (Idle, Berserk, Happy, Tamed) and transitions triggered by Buga’s inputs (e.g., “giving a flower” or “shouting commands”) illustrate key FSM elements, such as states, transitions, inputs, and outputs. A figshare package is provided at this link (Iudean and Vescan, 2025), containing the slide presentation and the video used in the study, along with the questionnaires of the study.

Rationale for the Storytelling Approach. The use of storytelling in STEM education, particularly for complex topics such as FSMs, is supported by research on narrative-based learning, which shows that stories can simplify abstract concepts by framing them in relatable and memorable scenarios (Barchas-Lichtenstein et al., 2023). In this case, the prehistoric storyline allows students to grasp the FSM concepts without needing prior technical knowledge, as they can intuitively follow Buga’s logical steps to understand each state transition. This approach leverages the natural human affinity for stories, which improves engagement and cognitive processing (Groshans et al., 2019). Additionally, by making Buga’s journey a discovery process, the video positions FSM concepts as tools for problem-solving, an approach that aligns with constructivist learning theories, where knowledge is built through experience and context.

3.3.2 FSM Concepts Illustrated in the Story

The video employs specific FSM components to construct a coherent and instructive storyline that builds students’ understanding incrementally:

States and Transitions: The mammoth’s behavior is modeled through distinct states, including “Idle”, “Berserk”, “Happy”, and “Tamed”, each triggered by Buga’s actions. For instance, poking the mammoth with a stick causes a transition from Idle to Berserk, while offering a flower moves it to a Happy state. These transitions illustrate how FSMs respond predictably to specific inputs, a foundational concept in FSM theory. This cause-effect relationship aids in reducing cognitive load, as it allows learners to focus on one clear state transition at a time, thereby reinforcing the concept of FSMs as a series of state-specific responses to inputs (Mou, 2024). Figure 1 depicts the beginning of the narrative, when the mammoth is in an Idle state and the protagonist aims to find a clear path to make it transition towards the Tamed state. In this process, the stone tables is used for traceability.

Figure 1: States and Transitions.

Inputs and Outputs: Inputs in FSMs drive transitions between states, and the video emphasizes this by associating each of Buga’s actions (e.g., “giving a flower” or “using polite language”) with specific behavioral changes in the mammoth. This representation helps students understand the principle of deterministic state transitions: given a specific state and input, the outcome is predictable. By presenting each input as a conscious choice by Buga, the video encourages viewers to see FSMs as tools for strategic planning and behavioral prediction, linking inputs and outputs in a way that supports applied understanding of FSM theory (Dochshanov and Tramonti, 2022). Figure 2 depicts the transition of the mammoth from the “Idle” state towards the “Happy” state based on a flower given as input.

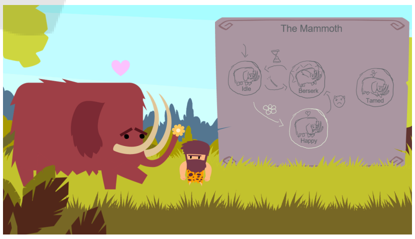

Figure 2: Inputs and Outputs.

The storyline subtly introduces the concept of determinism in FSMs by contrasting predictable responses (deterministic FSMs) with the mammoth’s unpredictable behavior, characteristic of non-deterministic FSMs. For example, when Buga attempts to tame the mammoth, his inputs sometimes fail to yield the expected outcomes, highlighting that non-deterministic FSMs can exhibit multiple possible behaviors given the same inputs. This concept is valuable in real-world applications, where systems may not always respond in a linear manner. This distinction prepares students to appreciate FSM complexity and variability in different contexts. Figure 3 depicts the confusion that the protagonist faces when trying to backwards engineer a non-deterministic FSM (the behavioral system of the mammoth) in contrast with the clarity of a deterministic FSM (the light switch system).

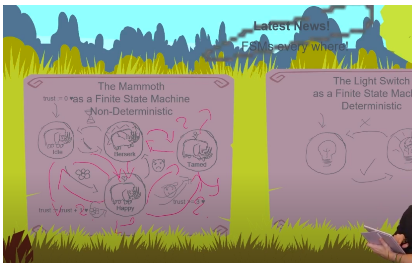

Figure 3: Non-deterministic and Deterministic FSMs.

3.3.3 Pedagogical Perspectives of the Teaching Material

Justification for the Multimodal Learning Approach. The video employs a multimodal approach to optimize comprehension by integrating auditory (narration), visual (animation), and textual (on-screen labels) elements. This design leverages Mayer's Cognitive Theory of Multimedia Learning, which suggests that combining visual and auditory information can enhance learning by activating both channels of the brain, thus reducing cognitive load and increasing retention (Mayer, 2005). The animations in the video provide visual cues for each state and transition, while the narration contextualizes these actions, making the FSM concepts accessible through multiple sensory modalities.

Each scene in the video follows a cycle: Buga performs an action (input), the mammoth reacts (transition), and a label appears on-screen to reinforce the state change visually. This structure aligns with multimodal reinforcement, as it helps students process the material in a layered manner, where each channel reinforces the others. For example, when Buga offers a flower to the mammoth, viewers see a visual cue (flower), hear an explanation of the action's purpose, and observe the state transition to "Happy", all of which contribute to a richer understanding of the FSM process.

Pedagogical Benefits of the Storytelling and Animation Integration. By embedding FSM concepts in a story, the video presents FSM principles in a relatable, problem-solving context. Research shows that learning is more effective when concepts are applied to realistic scenarios, fostering meaningful understanding and long-term retention (Bravo et al., 2021). Animation enhances this by visualizing state transitions, benefiting visual learners who may struggle with text-heavy representations. The video also reinforces learning through repeated exposure. Buga's interactions with the mammoth repeatedly demonstrate FSM elements such as "state", "transition", and "input", reinforcing understanding through varied narrative contexts. This aligns with spaced repetition theories, which support anchoring abstract principles to memorable actions (Ferri and Auerbach, 2012).

Educational Implications and Justification for the Approach. This narrative-driven, multimodal approach to FSM education is justified by its ability to cater to diverse learning styles, from visual to auditory and kinesthetic learners, by framing FSMs in a coherent storyline with corresponding animations and narration. This design supports engagement and conceptual clarity by leveraging multiple learning modalities, each reinforcing FSM principles through structured storytelling. By making complex concepts like FSMs accessible within a familiar, imaginative scenario, the video serves as both a cognitive aid and an engaging educational tool, aligning with the broader goals of immersive learning in technical disciplines (Wu et al., 2021).

3.4 Collecting Data by Administering Questionnaires

The timeline for the education activities is presented in Figure 4: a pre-test before the activity, then the dedicated activity to FSM concept, followed by a post-test, and finalizing with a feedback questionnaire specific to each group. Details about the administered questionnaires during the activity, along with the discussed concepts are provided next.

Study Design. This study followed a mixed design using both quantitative and qualitative analysis, by using a controlled experimental design with pre-test and post-test to assess students' understanding of FSM concepts before and after the instructional intervention. The timeline of activities was as follows.

Pre-Test. Both groups completed a pre-test to measure baseline knowledge of FSM concepts. The test consisted of multiple-choice and open-ended questions on FSM fundamentals, covering aspects such as state transitions, input/output definitions, and deterministic versus non-deterministic FSMs (Q1-Q7, Q8, Q9, Q10).

TakeHome-FSM Assignment. Following the pre-test, both groups were given the same FSM modeling assignment, which required them to design a finite state

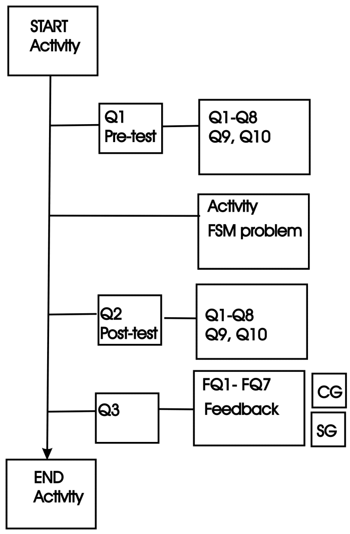

Figure 4: Schedule of the Administration of the Questionnaires.

machine for a microwave oven with five cooking functions. Students were expected to submit a diagram and an explanatory document detailing their FSM design process. This task aimed to assess practical application skills in FSM design (Ferri and Auerbach, 2012).The assignment was part of the formal assessment, aiming to address both major goals of learning as specified by Mayer (Mayer, 2009), namely *remembering* and *understanding*. The storytelling video content aims to also help students activate prior knowledge (Mayer, 2008) in order to integrate it with the verbal and pictorial models in working memory, in this way solving problems that were not explicitly given in the presented material, they must apply what they learned to a new situation.

Post-Test. After completing the assignment, a post-test was administered to measure knowledge gains (Q1-Q7, Q8, Q9, Q10). This test contained similar questions to the pre-test, designed to evaluate changes in comprehension of FSM concepts, particularly the ability to apply theoretical knowledge in practical scenarios (Yankovskaya and Yevtushenko, 1997). Bloom's Taxonomy (Thompson et al., 2008), which includes the six categories of Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation, relates directly to our study. By using open-ended questions based on real-life-like scenarios, the pre-test and post-test evaluated not only students' understanding of FSM concepts but also their ability to apply, analyze, and combine this knowledge in practical situations. This approach encouraged deeper thinking and problem-solving beyond theoretical learning.

Feedback Questionnaire. A feedback questionnaire was distributed to collect qualitative data on the students' perceptions of their learning experience. Group SG students were specifically asked about their engagement with the storytelling approach and whether they felt it aided their understanding of FSM concepts. Responses were collected on a 5-point Likert scale, with additional open-ended questions for more detailed feedback (FQ1-FQ7 specific questions for the SG group). To facilitate the replication of the study, the questionnaires and the teaching materials will be available after the review process using a public research artifact repository to store the replication package as mentioned in Section 3.3.1.

Groups and Instructional Differences. The main instructional difference between Group CG and Group SG was the teaching method within a take-home assignment activity. Group CG followed a conventional FSM instruction module, while Group SG was instructed through video storytelling. By comparing these groups, we aimed to assess the impact of storytelling-based learning on understanding FSM principles, examining whether the storytelling approach increased engagement and comprehension compared to traditional methods (Hacker and Sitte, 1999).

Data Analysis. Quantitative data was collected from the pre-tests and post-tests to measure knowledge acquisition, and statistical analysis (MacFarland and Yates, 2016) was performed to determine any significant differences in learning outcomes between the two groups. Qualitative feedback (Patton, 2015) from the questionnaires provided insights into students' subjective learning experiences, helping to assess the perceived effectiveness of the storytelling approach.

4 ANALYSIS OF RESULTS

This section presents the findings of the study, combining quantitative analysis of pre-test and post-test scores with qualitative insights from participant feedback. The results are structured to address the research questions.

4.1 Measurable Differences in Learning Outcomes (RQ1)

Discussion of Question Types and Measurability. The pre-test and post-test evaluations included questions that assessed both **Foundational Knowledge** and **Application Skills**. Foundational knowledge was assessed using questions about FSM states, transitions, and determinism directly measured conceptual understanding (questions Q1-Q8), and application skills were assessed using scenario-based questions that required participants to apply their knowledge to practical problems, such as designing FSMs for real-world systems (e.g., microwaves and vending machines) (questions Q9 and Q10).

To assess measurable differences in learning outcomes, pre-test and post-test scores were analyzed for the CG (control) and SG (storytelling) groups. Table 1 summarizes the average scores and score improvements. It may be noticed that the pre-test for CG and SG groups are very similar, namely, 8.79 for CG and 8.75 for the SG group, interpreting that the two groups had similar knowledge before the activity. Regarding the post-test, the values for the CG and SG are again similar, however, even if both decreased, the value for the SG group decreased with fewer points.

Table 1: Average Pre-Test and Post-Test Scores by Group.

Group	Avg. Pre-Test	Avg. Post-Test
CG	8.79	8.55
SG	8.75	8.53

The pre-test and post-test results for the two groups may be also view in Figure 5 and Figure 6. In both cases, pre-test and post-test, there are questions that the SG groups answered better than the CG group: for pre-test with questions Q2, Q5, Q6, and Q8; for post-test with questions: Q1, Q5, Q6, and Q7.

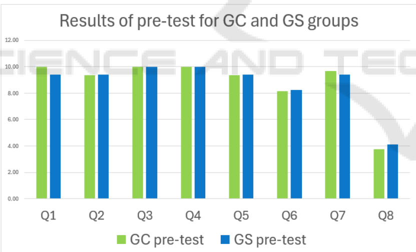

Figure 5: Results of pre-test (Q1-Q8) for CG and SG groups.

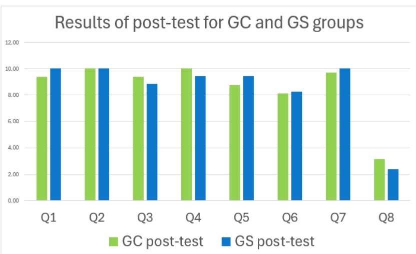

Figure 6: Results of post-test (Q1-Q8) for CG and SG groups.

Findings. Based on the pre-test and post-test results, the following distinctions can be made between the study groups:

- **SG Group.** Participants did not show an improvement from the pre-test to post-test, moreover, a slight decrease in the score was observed (from 8.75 to 8.53.
- **CG Group.** Participants experienced a slight decline in post-test scores (-0.24 points).
- For both groups (CG and SG) was observed this slight decline, however, less points for the SG (only -0.22).

Kruskal-Wallis statistical test (MacFarland and Yates, 2016) was performed considering various perspectives: considering the pre-test of both groups, the result is not significant at $p < .05$ (p=1), thus emphasizing on the fact that the students in the two groups have similar knowledge about FSM. The same result is obtained considering the post-test results of the two groups (p=1). When comparing the results of the pre-test and post-test for the CG group, the test showed that the result is not significant $p < .05$ (p=0.59951), and the same not significant result for SG group considering pre-test and post-test (p=0.95812).

4.2 Improvement in Understanding FSMs (RQ2)

Open-ended responses (Q9 and Q10) were analyzed to evaluate participants' understanding of FSMs. These responses highlighted practical examples and insights into abstract concepts like non-determinism. The themes regarding *understanding of FSM* by students were identified through qualitative analysis (Patton, 2015), first by open coding and then using axial coding, use the *FSM understanding codes* included into the thematic analysis. For each group, we describe the obtained themes individually in Table 2 and further illustrate them with quotes and excerpts from the data.

Remark: For anonymization purposes, all quotes have been translated into a non-gender specific form if possible or into a gender-specific form, masculine).

Group CG: provided more technical examples, focusing on well-defined systems. For example, one participant described an ATM FSM: "In an ATM, FSM represents states like card insertion, PIN entry, and transaction selection, with outcomes like successful completion or insufficient funds.". Another participant used the elevator system as an example: "The elevator can be in states like idle, moving, or door open, with transitions triggered by button presses." These examples reflect the clear, deterministic nature of FSMs in structured systems.

Group SG: in contrast, gave examples showing more flexibility in FSMs. One participant mentioned the

Table 2: Themes from Open-Ended Responses.

Theme	CG	SG
FSM Applications (Q9)	ATM behavior, traffic systems	Traffic lights, vending machines, programmable devices
Non-Determinism (Q10)	Concurrent systems, complex models	Flexibility, real-world scenarios
Engagement	Brief, technical responses	Detailed, contextual examples

microwave: "In a microwave, FSM can transition from idle to multiple states based on user actions, like selecting cook or stop." Another example was a traffic light system: "The traffic light can change between states, but transitions may vary depending on time or sensor inputs." These examples highlight Group SG's understanding of FSMs in dynamic, real-world scenarios, where transitions can be non-deterministic.

Findings. Based on this subtle, yet relevant, trend of answers in the open-ended questions, the following conclusions can be formulated:

- **FSM Applications.** SG participants provided richer and more relatable examples (e.g., programmable devices), while CG responses were concise and technical.
- **Understanding Non-Determinism.** SG responses emphasized practical implications, such as flexibility in handling uncertainty, whereas CG responses focused on formal definitions.
- **Engagement and Depth.** SG participants' responses reflected greater engagement with the material, likely due to the narrative context provided in the video.

4.3 Engagement and Perception of Learning FSMs (RQ3)

To assess engagement and perception, Likert-scale feedback from SG participants was analyzed. Table 3 presents average ratings for key questions related to engagement, clarity, and applicability.

Findings. Based on the self-reflective feedback scoring collected from the students, the following conclusions can be formulated:

- **Engagement (FQ1).** SG participants found the storytelling video engaging, with an average rating of 4.41.

Table 3: Average Likert Ratings for SG Engagement and Perception.

#Q	Question	Avg.(1–5)
FQ1	The video held my complete attention.	4.41
FQ2	The story was easy to follow and the analogies were clear.	4.82
FQ3	The story made the subject more tangible and understandable.	4.65
FQ4	The story enhanced my understanding of FSM.	4.41
FQ5	I would like to participate in future storytelling-based learning.	4.00
FQ6	I believe I can apply what I learned in the workplace.	3.53
FQ7	The video changed my perspective on FSM.	4.00

- **Clarity (FQ2, FQ3).** Participants rated the story as clear and relatable, with Q2 and Q3 receiving the highest scores (4.82 and 4.65, respectively).
- **Perception and Application (FQ6, FQ7).** While participants moderately agreed they could apply the material in their workplace (3.53), they strongly agreed that the video changed their perspective on FSM (4.00).

Qualitative Feedback Themes. Open-ended responses further highlighted the storytelling approach's impact:

- **Engagement.** Many participants noted that the narrative format helped maintain their interest and made the learning experience enjoyable.
- **Retention.** The use of relatable analogies and examples was frequently mentioned as aiding memory retention.
- **Challenges.** A few participants suggested that the storytelling could be less effective for highly technical learners who prefer concise explanations.

4.4 Answers to the Research Questions

Answer RQ1: Storytelling-driven video content did not leads to measurable improvements in learning outcomes, as reflected in post-test score that decreased for SG participants. However, the qualitative analysis showed better results regarding the application skills for the SG group when compared with the CG group.

Answer RQ2: The storytelling approach improves understanding of FSMs by providing relatable and detailed contexts. The storytelling approach helped improve students' understanding of FSMs by providing *more relatable and detailed examples. SG participants showed a better ability to connect FSM concepts to real-life situations, such as traffic lights and vending machines, which made the concepts easier to understand. In their feedback, SG students often used real-world examples to explain FSMs, showing a deeper understanding. In contrast, CG responses were more technical and abstract, which might have made the concepts harder to relate to everyday life.*

Answer RQ3: Storytelling enhances engagement and positively influences perceptions of FSM learning, although its applicability may vary based on learning preferences. SG participants rated the video highly for attention and clarity, with scores of 4.41 and 4.82 (out of 5 maximum). Many students said the story kept them interested and helped them understand FSM concepts better. However, some students felt that the storytelling approach might not work as well for learners who prefer short, direct explanations. Overall, the feedback showed that storytelling can make FSMs more engaging and help students see the subject in a new way.

5 DISCUSSION

This section interprets the results in light of the research questions, focusing on their significance for teaching finite state machines (FSMs) and computational models. It also highlights challenges observed during the study, setting the stage for the subsequent sections on implications and future work.

5.1 Interpreting the Results

5.1.1 Measurable Learning Outcomes (RQ1)

The study found no significant differences in learning outcomes between the SG (storytelling) and CG (control) groups, as indicated by similar pre- and post-test score changes. The SG group's slight decrease of -0.22 points suggests that while storytelling may enhance engagement, its direct impact on learning outcomes requires further investigation. Likewise, the CG group's drop of -0.24 points points to potential limitations of traditional instruction in maintaining student retention. While the results do not strongly support a clear advantage for storytelling, they align with multimodal learning theories (Bouchey et al., 2021), which suggest that integrating visual, verbal, and contextual elements could help address retention challenges observed in both groups.

Insights on Question Design and Performance. The inclusion of foundational and applied questions provided a well-rounded measure of student performance.

Foundational Knowledge: Questions focused on FSM states and transitions revealed that SG participants retained these concepts more effectively, likely due to repeated exposure through the narrative framework.

Applied Knowledge: Scenario-based questions demonstrated the SG group's ability to contextualize and apply FSM principles, an outcome that aligns with prior findings on the role of storytelling in STEM education.

These results underscore the need for instructional content *to balance theoretical rigor with engaging, relatable contexts to maximize learning outcomes.*

5.1.2 Enhanced Understanding of FSMs (RQ2)

Qualitative responses highlighted key differences in how the two groups understood FSMs. SG participants consistently provided more detailed and contextualized answers to open-ended questions. For example, their responses to Q9 included practical and relatable examples, such as vending machines and programmable devices, whereas CG participants focused on abstract descriptions like ATM behavior.

In Q10, which explored non-determinism, SG participants elaborated on the flexibility and real-world implications of FSM models. These findings suggest that storytelling not only improves comprehension but also enhances the ability to articulate and apply complex concepts. The narrative approach likely bridges the gap between theoretical abstraction and practical relevance, making FSMs more accessible and engaging.

5.1.3 Engagement and Perception (RQ3)

Feedback data provided compelling evidence of the storytelling approach's impact on engagement and perception.

Engagement. Participants from Group SG rated the video highly for attention and clarity, with average scores of 4.41 and 4.82 (out of 5 maximum), respectively. One student mentioned, "It was an interesting experience to follow and analyze each step", and another said, "The video kept me engaged." These responses highlight the storytelling approach's ability to actively capture students' attention, aligning with active learning theories that emphasize emotional and cognitive engagement.

Perception. The majority of participants expressed interest in future storytelling-based learning, rating

it 4.00. One participant noted, “I would like more videos like this”, while another shared, “It was a fun and creative way of learning something.” These statements reflect the positive impact of storytelling on students’ perceptions, indicating that it changed their perspective on FSMs and made learning more enjoyable.
Applicability. Regarding the workplace applicability of FSM concepts, participants rated it 3.53. One response highlighted, “FSM is a useful tool that can help us develop efficient and bug-free systems.” Another participant mentioned, “Learning more about FSM and trying to understand a situation better by creating a story around it.” These insights suggest that while students acknowledged the workplace relevance of FSMs, they also recognized how storytelling helped solidify their understanding of these concepts by anchoring them in relatable contexts.
Negative Feedback. Despite these positives, some participants pointed out the potential drawbacks of storytelling. One student shared, “It was an interesting experiment, although it didn’t do much for me to better understand the subject discussed”, while another commented, ”This topic can be presented in a few minutes, and the storytelling felt time-consuming.” These responses indicate that for some, the storytelling approach may not be as effective for quickly grasping technical material. Despite these strengths, some feedback pointed to the potential limitations of storytelling, such as its perceived inefficiency for highly technical learners who prefer concise explanations.

5.2 Emerging Challenges and Considerations

While the results affirm the benefits of narrative-driven content, several challenges emerged:

- *Balancing Engagement with Rigor*. The storytelling approach successfully engaged participants but may require supplemental technical explanations to satisfy diverse learner preferences.
- *Content-Specific Effectiveness*. The observed benefits were specific to FSM concepts, raising questions about the generalisability of storytelling to other computational topics.
- *Assessing Long-Term Impact*. The study focused on immediate learning outcomes. Longitudinal studies are needed to evaluate the lasting effects of storytelling on retention and application.

6 IMPLICATIONS AND FUTURE WORK

The findings of this study provide important insights into the potential of storytelling as a teaching method in computational fields. This section explores the implications for FSM and computational model instruction, practical recommendations for educators, and directions for future research.

6.1 Implications for Teaching FSM and Computational Models

Engagement-Driven Learning. The storytelling approach demonstrated its ability to captivate learners and foster deeper understanding of FSM concepts. This emphasizes the need to integrate engaging, narrative-based materials into traditionally technical curricula.
Contextual Learning. By embedding abstract concepts in relatable scenarios, storytelling helps bridge the gap between theoretical knowledge and practical application. This approach could enhance student outcomes in other computational topics, such as automata theory and control systems.
Diverse Learning Preferences. While storytelling was effective for most participants, feedback highlighted the need to accommodate varying preferences. Combining narrative elements with direct, technical instruction could better serve learners who prefer concise and factual content.

6.2 Recommendations for Teachers

Incorporate Multimodal Content. Educators should leverage multimedia storytelling tools, including animations and real-world analogies, to enhance student engagement.
Balance Narrative with Technical Depth. To address the needs of diverse learners (Fleming and Mills, 1992), combine storytelling with supplementary materials such as detailed diagrams, mathematical proofs, or step-by-step walkthroughs.
Iterative Feedback Loops. Actively collect and analyze student feedback to refine storytelling methods and tailor instructional content to evolving needs.

6.3 Future Research Directions

Building on the findings of this study, future research should focus on the following.
Long-Term Retention. Investigate the lasting effects of storytelling on knowledge retention and practical application, using longitudinal studies.

Generalizability Across Topics. Explore the effectiveness of narrative-based teaching in other areas of computational science, such as algorithm design or data structures.
Personalized Learning. Assess how storytelling impacts different learner profiles, considering factors such as prior knowledge, cultural background, and individual preferences.

7 THREATS TO VALIDITY

Several risks to the validity of the findings were considered and addressed. To minimize bias, students were randomly assigned to either the CG or SG group, and pre-tests ensured similar baseline knowledge of FSM concepts. External factors like student motivation were controlled by maintaining consistent testing conditions and providing equal attention to both groups. Although tests were not anonymous, students were encouraged to provide honest feedback by stressing the importance of candid responses. Additionally, recognizing that some students may prefer traditional instruction, both quantitative and qualitative data were used to capture diverse learning preferences and evaluate the storytelling approach.

8 CONCLUSIONS

This study examined the impact of storytelling-based video content on the learning of finite state machines (FSMs) compared to traditional instructional methods. Key findings include the following:
Learning Outcomes. There was no significant improvement in post-test scores, indicating that storytelling alone may not directly enhance learning performance.
Understanding. Storytelling helped participants contextualize abstract FSM concepts and relate them to real-world applications.
Engagement. Feedback from Likert-scale ratings and open-ended responses confirmed increased attention and positive perceptions of learning FSMs.

The study suggests that the main benefit of storytelling is its ability to contextualize abstract concepts rather than directly improving problem-solving skills, emphasizing the need for more research to balance narrative-driven content with technical rigor and explore its long-term effects.

ACKNOWLEDGEMENTS

The publication of this article was partially supported by the 2024 Development Fund of the Babes-Bolyai University.

REFERENCES

Angel-Fernandez, J. M. and Vincze, M. (2018). Introducing storytelling to educational robotic activities. In *2018 IEEE Global Engineering Education Conference (EDUCON)*, pages 608–615. IEEE.

Barchas-Lichtenstein, J., Sherman, M., Voiklis, J., and Clapman, L. Science through storytelling or storytelling about science? identifying cognitive task demands and expert strategies in cross-curricular stem education. In *Frontiers in Education*, volume 8, page 1279861. Frontiers.

Barchas-Lichtenstein, J., Sherman, M., Voiklis, J., and Clapman, L. (2023). Science through storytelling or storytelling about science? identifying cognitive task demands and expert strategies in cross-curricular stem education. In *Frontiers in Education*, volume 8, page 1279861. Frontiers Media SA.

Berreth, T., Polyak, E., and Fitzgerald, P. (2020). Story-go-round: Augmented reality storytelling in the multidisciplinary classroom. Cited by: 1.

Bouchey, B., Castek, J., and Thygeson, J. (2021). Multimodal learning. *Innovative Learning Environments in STEM Higher Education: Opportunities, Challenges, and Looking Forward*, pages 35–54.

Bravo, F. A., Hurtado, J. A., and González, E. (2021). Using robots with storytelling and drama activities in science education. *Education Sciences*, 11(7):329.

Collins, S., Steele, T., and Nelson, M. (2023). Storytelling as pedagogy: The power of chemistry stories as a tool for classroom engagement. *Journal of Chemical Education*, 100(7):2664–2672.

Dekeyser, J.-L. and Aljendi, A. S. (2015). Adopting new learning strategies for computer architecture in higher education: case study: building the s3 microprocessor in 24 hours. In *Proceedings of the Workshop on Computer Architecture Education*, pages 1–8.

Dengel, A. (2018). Seeking the treasures of theoretical computer science education: Towards educational virtual reality for the visualization of finite state machines. In *2018 IEEE international conference on teaching, assessment, and learning for engineering (TALE)*, pages 1107–1112. IEEE.

Dochshanov, A. and Tramonti, M. (2022). Digital storytelling and games to stem skills development. In *EDULEARN22 Proceedings*, pages 8503–8511. IATED.

Durak, H. Y. (2018). Digital story design activities used for teaching programming effect on learning of programming concepts, programming self-efficacy, and participation and analysis of student experiences. *JOURNAL OF COMPUTER ASSISTED LEARNING*, 34(6):740–752.

Ferri, B. H. and Auerbach, J. L. (2012). A portable finite state machine module experiment for in-class use in a lecture-based course. In *2012 ASEE Annual Conference & Exposition*, pages 25–89.

Fleming, N. D. and Mills, C. (1992). Not another inventory, rather a catalyst for reflection. *To Improve the Academy*, pages 137–155.

Groshans, G., Mikhailova, E., Post, C., Schlautman, M., Carbajales-Dale, P., and Payne, K. (2019). Digital story map learning for stem disciplines. *Education Sciences*, 9(2):75.

Hacker, C. H. and Sitte, R. (1999). Implementing finite state machines in a computer-based teaching system. In *Education in Microelectronics and MEMS*, volume 3894, pages 110–117. SPIE.

Henry, J., Dumas, B., Vescan, A., and Pasca, A. M. (2022). Student misconceptions about finite state machines: Identify them in order to create a concept inventory. In *Proceedings of the 4th International Workshop on Education through Advanced Software Engineering and Artificial Intelligence*, pages 2–9.

Heymann, R. and Greeff, J. J. (2018). Designing and developing a narrative driven serious game for teaching information theory. In *2018 IEEE Global Engineering Education Conference (EDUCON)*, pages 489–496. IEEE.

Hill, S. and Grinnell, C. (2014). Using digital storytelling with infographics in stem professional writing pedagogy. In *2014 IEEE International Professional Communication Conference (IPCC)*, pages 1–7.

Iudean, B. and Vescan, A. (2025). Narrative-driven learning: Teaching finite state machines through storytelling. *https://doi.org/10.6084/m9.figshare.28436603.v1*.

Joseph, S., Schumm, M., Rummel, O., Soska, A., Reschke, M., Mottok, J., Niemetz, M., and Schroll-Decker, I. (2013). Teaching finite state machines with case method and role play. In *2013 IEEE Global Engineering Education Conference (EDUCON)*, pages 1305–1312. IEEE.

Karttunen, L. (2000). Applications of finite-state transducers in natural language processing. In *International Conference on Implementation and Application of Automata*, pages 34–46. Springer.

Landrum, R. E., Brakke, K., and McCarthy, M. A. (2019). The pedagogical power of storytelling. *Scholarship of Teaching and Learning in Psychology*, 5(3):247.

Lee, D. and Yannakakis, M. (1996). Principles and methods of testing finite state machines-a survey. *Proceedings of the IEEE*, 84(8):1090–1123.

MacFarland, T. W. and Yates, J. M. (2016). *Kruskal Wallis H-Test for Oneway Analysis of Variance (ANOVA) by Ranks*. Springer International Publishing, Cham.

Mayer, R. E. (2005). *The Cambridge handbook of multimedia learning*. Cambridge university press.

Mayer, R. E. (2008). Applying the science of learning: Evidence-based principles for the design of multimedia instruction. *American Psychologist*, 63(8):760–769.

Mayer, R. E. (2009). *Multimedia learning (2nd ed.)*. Cambridge university press.

Min, W., Mott, B., Park, K., Taylor, S., Akram, B., Wiebe, E., Boyer, K. E., and Lester, J. (2020). Promoting computer science learning with block-based programming and narrative-centered gameplay. In *2020 IEEE Conference on Games (CoG)*, pages 654–657. IEEE.

Mou, T.-Y. (2024). The practice of visual storytelling in stem: Influence of creative thinking training on design students' creative self-efficacy and motivation. *Thinking Skills and Creativity*, 51:101459.

Nadeem, M., Lal, M., Cen, J., and Sharsheer, M. (2022). Ar4fsm: Mobile augmented reality application in engineering education for finite-state machine understanding. *Education Sciences*, 12(8):555.

Parham-Mocello, J., Ernst, S., Erwig, M., Shellhammer, L., and Dominguez, E. (2019). Story programming: Explaining computer science before coding. In *Proceedings of the 50th ACM Technical Symposium on Computer Science Education*, pages 379–385.

Patton, M. Q. (2015). *Qualitative Research & Evaluation Methods: Integrating Theory and Practice*. Sage, Los Angeles, CA, fourth edition.

Radojevic, I. and Salcic, Z. (2011). *Embedded systems design based on formal models of computation*. Springer Science & Business Media.

Resnyansky, D. (2020). Augmented reality-supported tangible gamification for debugging learning. In *2020 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE)*, pages 377–383. IEEE.

Segel, E. and Heer, J. (2010). Narrative visualization: Telling stories with data. *IEEE transactions on visualization and computer graphics*, 16(6):1139–1148.

Thompson, E., Luxton-Reilly, A., Whalley, J. L., Hu, M., and Robbins, P. (2008). Bloom's taxonomy for cs assessment. In *Proceedings of the tenth conference on Australasian computing education-Volume 78*, pages 155–161.

Wu, C., Tang, Y., Tsang, Y., and Chau, K. (2021). Immersive learning design for technology education: A soft systems methodology. *Frontiers in Psychology*, 12:745295.

Wu, J. and Chen, D.-T. V. (2020). A systematic review of educational digital storytelling. *Computers & Education*, 147:103786.

Yankovskaya, A. and Yevtushenko, N. (1997). Finite state machine (fsm)–based knowledge representation in a computer tutoring system. *New Media and Telematic Technologies for Education in Eastern European Countries*, pages 67–74.