„BABEȘ-BOLYAI UNIVERSITY” CLUJ-NAPOCA
FACULTY OF PSYCHOLOGY AND EDUCATIONAL SCIENCES
DOCTORAL SCHOOL “DIDACTICS. TRADITION, DEVELOPMENT, INNOVATION”

ABSTRACT OF DOCTORAL THESIS

USE OF ANIMATED FILMS IN PRIMARY SCHOOL EDUCATION, SCIENCES

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DECLARATION

The undersigned, Sanda Vereș, being a doctoral student at "Babeș-Bolyai" University, declare the following:

- The doctoral thesis titled "The Use of Animated Films in Primary Education, in Science" was carried out in strict compliance with the four values of academic integrity – honesty, responsibility, replicability, and validity of knowledge.
- The similarity analysis of the doctoral thesis was conducted at the Doctoral School "Didactics. Tradition, Development, Innovation," using the Turnitin Report.
- The thesis complies with the drafting standards specified in the APA Publication Manual (7th Edition), except for the 1.5 line spacing.
- The published studies address the issues of the present research and are cited in the thesis.

5 June 2024

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LIST OF ABBREVIATIONS AND ACRONYMS

EIMA	—	Engage – Investigate – Model – Apply
ERR	—	Evocare – Realizarea sensului – Reflecție
FCM	—	Flipped classrom Model
GE	—	Experimental Group
GC	—	Control Group
GDPR	—	General Data Protection Regulation
IB-FC	—	Inquiry-based Flipped Classroom Model
IC-FCM	—	In Class Flipped Classroom Model
MEN	—	Ministry of National Education
p.	—	page
PÎP	—	Primary School Teachers
pp.	—	pages

Keywords: animation film, instructional models, science, primary school education

CHAPTER I. THEORETICAL FRAMEWORK

1.1. Introduction and Research Problem

Our interest in studying the use of animated films in science learning is based on several premises: knowledge of the rapid development of technology and its impact on human society, including activities in educational institutions and children; awareness of primary school students' interest in multimedia in general and animated films in particular; our own professional competencies and personal beliefs about facilitating understanding of scientific processes and systems through dynamic representations such as animations; awareness of the controversial conclusions of studies claiming bias and methodological gaps or deficiencies in research on the effects of animated films on science learning; knowledge of researchers' conclusions, issues, and recommendations regarding the use of animated films in science learning in primary education. Our research aims to provide a response that facilitates primary education teachers' adaptation to technological progress and the multitude of multimedia resources available today.

1.2. Theoretical Landmarks Regarding Animated Films

In scientific works, various terms are used to refer to the specific movement of animations. Dictionaries and studies present definitions of animation and animated film, highlighting some essential features, but without exhaustive coverage. Animation is described from several perspectives: as art, as an artistic process, as an application, as a mode of presentation or display, and as a product.

Based on the definitions and descriptions in the reviewed works, it is noted that animations belong to the category of external visual representations, perceived through the visual analyzer, distinguishing them from external auditory representations, which are perceived through the auditory analyzer. Some animations, accompanied by auditory information, can be classified as multimodal or multimedia representations, perceived through both the visual and auditory channels. Unlike mental representations, which occur naturally in the human mind, animations are artificial constructions or representations created by humans using various means, procedures, and techniques.

Considering that animations do not faithfully represent reality but rather in forms with varying degrees of similarity to reality, that they represent hypothetical cases rather than concrete cases from reality, and that they present subjects selectively with some non-visual aspects, animations are classified as abstract representations. Of course, there are animations that represent aspects nonexistent in reality or that represent reality with a high degree of fidelity or similarity, but this thesis investigates animations intended for science learning, not those in the arts domain.

The most important property of animations is their representation of movement, thus categorized as dynamic representations alongside films and videos, which faithfully represent aspects of reality. In static representations, the image or visual representation does not change over time from the observer's perspective. Animations thus differ from static representations, which include photographs, drawings, paintings, maps, diagrams, and schemes.

In conclusion, animations are visual, artificial, abstract, dynamic representations of aspects of reality or imagination.

Based on the literature, animated films have been classified based on 24 criteria. The classification was represented in an original tree-like scheme, with each category of animated films described in text. The literature specifies certain purposes and functions of visual representations, including animations. Among the multitude of functions of animated films, several functions were detailed in this thesis: representational, decorative, demonstrative, directive or attention-guiding, stimulative, informative, cognitive-formative, mnemonic, and ergonomic.

1.3. Theories Underpinning Learning Through Animated Films in Science

Researchers are concerned with explaining how learning occurs through the use of animated films in various contexts and by comparing them with other external representations. Science learning through watching animated films should consider a set of theories that complement each other: "working memory theory" (Baddeley, 1986), "dual coding theory" (Clark & Paivio, 1991; Paivio, 1986), "schema theory" (Miller, 1956; Thorndyke & Hayes Roth, 1979; Rumelhart, 1981), "cognitive load theory" (Chandler & Sweller, 1996; Sweller et al., 1998), and "cognitive theory of multimedia learning" (Mayer, 1997; Schnotz, 2005). The thesis selectively presents relevant aspects of these theories that provide insights into understanding science learning resulting from the viewing of animated films. These theories explain how verbal information is perceived through the auditory channel and visual information through the visual channel, how this information is processed in working memory, and how it is stored in long-term memory.

1.4. Current State of the Field

Internationally, a large number of studies indicate significant interest in the use of animated films in science education, both at pre-university and university levels. To provide an overview of the research conducted, I first present several insights extracted from various meta-analyses and recent reviews (Berney & Betrancourt, 2016; Bétrancourt & Tversky, 2000; Castro-Alonso et al., 2016; Tversky et al., 2002; Hoffler & Leutner, 2007), which aimed to identify studies comparing the effectiveness of using animated films versus static visual materials in learning across different science domains.

To gain a comprehensive view of the topics studied through animated films, I analyzed research identified in the global literature that meets several criteria: animations are used for learning; students, pupils, or other adults are involved; learning activities target science-related themes; content could be studied in science education at the pre-university level; the research was conducted and published after the year 2000. The selection includes 41 studies from the fields of physics, biology, chemistry, geology, astronomy, and meteorology. To provide a synthesized view of these studies, the thesis includes detailed information in data tables.

Regarding Primary Initial Education (PIE) teachers' opinions on the use of animated films in science learning at the primary education level, there are few studies globally that investigate teachers' opinions (Aslan et al., 2021) and future teachers' opinions (Birisci et al., 2010; Çinar & Kurt, 2019).

Regarding experimental research involving primary education students or similar-aged children, where learning activities with science themes use animations, 17 experimental, quasi-experimental, and action research studies have been identified in the global literature. Studies were selected based on criteria such as describing experimental, quasi-experimental, or action research; students aged between 6.5 years and 11-12 years; specifying primary school grade or level; and activities involving the creation and/or viewing of animations by students. In addition, five studies conducted in primary education investigated the flipped classroom model using videos. There is diversity in the aspects studied in the selected research, a greater interest in such studies in multiple countries (Romania, Greece, Indonesia, Turkey, Nigeria, Cyprus), incomplete descriptions of the research, and better results obtained in science by students who watched animated films in various educational contexts.

1.5. Relevance of the Research

Investigating PIP opinions on the use of animated films in science learning (Study 1) is important because PIP's beliefs about animated films, their effects on children, and how they are used in teaching influence the design, organization, and assessment of science instruction and learning. These data allow for comparing PIP opinions from Romania with those from other countries and reporting them on a global scale, even though these opinions have been explored in few studies. Furthermore, the results enable comparing them with our own views on using animated films in science learning to understand the real context for conducting experimental research and implementing formative interventions based on animated films whose effectiveness will be tested.

Researching instructional models based on animated films (Study 2) is important because it identifies contexts conducive to enhancing learning efficiency through viewing animated films with specific science content. Only 12 studies have detailed descriptions of 20 instructional models, variations thereof, or strategies in which animated films are used in the literature. Study 2 is relevant for rigorously analyzing these models used or proposed by researchers; identifying stages described in studies; establishing categories of instructional models; systematizing these models and their stages in data tables; and representing instructional models and strategies in circular scheme diagrams, even though such visual representations were not included in researchers' works.

The relevance of quasi-experimental studies (Studies 3, 4, and 5) stems from comparing the effects of instructional models based on viewing animated films with those based on observing schematic or illustrative drawings (captured from animated films) or listening to texts similar to those in animated films in various educational contexts.

CHAPTER II OBJECTIVES AND GENERAL METHODOLOGY OF THE RESEARCH

2.1. Research Objectives

2.1.1. General Objectives

This thesis aims to investigate the preparation and use of animated films in science learning at the primary education level from theoretical, methodological, and practical perspectives. Therefore, this research pursues three main objectives:

1. To investigate PIP opinions regarding the selection, processing, and use of animated films in science learning in primary education.
2. To identify and describe instructional models based on animated films used or usable in science learning.
3. To investigate the effects of specific instructional models, methods, and strategies based on animated films on students' acquisition of knowledge in science at the primary education level.

2.1.2. Specific Objectives

The first general objective is achieved through Study 2, which involves a questionnaire survey to collect and analyze PIP opinions about the selection, processing, and use of animated films in science learning in primary education. The second general objective is also addressed by Study 2, premised on the absence of meta-analyses or other reviews in the global literature presenting instructional models based on animated films used or usable in science learning. The third general objective is pursued through Studies 3, 4, and 5, which are all based on literature review, the authors' teaching concepts, and understanding the importance of multimodal learning through viewing animated films and observing drawings, using observation as a natural skill, a teaching method, and a scientific method.

2.2. General Methodology

This research includes a quantitative study utilizing questionnaire surveys, a qualitative study involving narrative literature review, and three quasi-experimental studies. We have outlined general methodological aspects concerning population selection for research, overall research designs, measurement instruments used, and data analysis procedures.

CHAPTER III: ORIGINAL RESEARCH CONTRIBUTIONS

This chapter presents five studies with significant original contributions: a study on teachers' opinions regarding the selection, processing, and use of animation films in science learning, a study focusing on models and instructional strategies described in literature utilizing animation films to facilitate science learning, and three quasi-experimental studies on elementary school students' knowledge acquisition in science through watching animation films using specific instructional models and strategies.

3.1. Study 1: Primary School Teachers' Opinions on the Use of Animation Films in Science Learning

3.1.1. Introduction

From the analysis of studies conducted worldwide, there is little interest in studying teachers' opinions regarding the selection, processing, and use of animations in teaching and learning science, with much of the data collected by researchers from Turkey focusing only on specific issues related to the use of animation films. In this context, our study aims to obtain a comprehensive overview through the application of a questionnaire, both regarding the selection and preparation of animations for lessons, as well as their use in teaching. To conduct our study, four research questions were formulated:

1. What are the factors influencing teachers' decisions in selecting and processing animation films for science learning?
2. What are the factors influencing teachers' decisions in using animation films for science?
3. What correlations exist between the factors influencing teachers' decisions in selecting and processing animation films for science learning?
4. What correlations exist between the factors influencing teachers' decisions in using animation films for science?

This chapter delves into these aspects, providing detailed insights into the perceptions and practices of primary school teachers concerning the integration of animation films in science education.

3.1.2. Method

Participants

This study involved 453 primary school teachers (PÎP) with diverse characteristics (gender, age, educational level, teaching experience, pedagogical rank, school location, county, and class taught). The selection of participants was based on criteria including: (a) being a primary school teacher, and (b) being employed within the education system.

Data Collection

Data were collected through a survey conducted from August to November in 2022. A questionnaire created in Google Drive was utilized as the data collection instrument, administered online. Participant selection employed a non-conventional method known as "snowball sampling." Throughout the research, confidentiality of personal data of the participants was strictly maintained, adhering to legal and ethical requirements stipulated for research, ensuring data protection in accordance with the General Data Protection Regulation (GDPR) (2018).

Instrument

The data collection instrument for the community of primary school teachers was designed by the researcher based on analysis of the school curriculum, recommendations and examples from educational literature, observations, and the researcher's experience in working with students, as well as information related to the use of animations in science lessons. The questionnaire items underwent validation by two experts in science education didactics and psychopedagogy. The questionnaire comprises three sections. Section I**:** "Information regarding the selection and processing of animation films for teaching activities," consisting of 53 items or indicators associated with 8 factors: film sources; internet and technology; film characteristics; teacher's purposes and motives; teacher's competence; subject discipline; learning content; student characteristics. Section II**:** "Information regarding the use of animation films in teaching activities," comprising 60 items or indicators associated with 8 factors: access to technology and internet; purpose of use; timing of viewing; methods; student attention, interest, and motivation; understanding; learning/memory; teacher's and student's competence.The first two sections total 113 items, with responses rated on a Likert scale from 1 to 5, where 1 (not important at all/no problem), and 5 (very important/big problem). Respondents were instructed to assign 5 points if the statement applied very well to them, 1 point if it did not apply at all, and between 2 to 4 points if it applied to some extent. Section III**:** "Participant Information": gender, age, educational level, teaching experience, pedagogical rank, school environment, county, and class taught.

Data Analysis

Preliminary Analyses Conducted on the Instrument Used

To ensure the questionnaire items accurately measured the researched aspects, and to measure internal consistency or reliability of the research instrument, Cronbach's Alpha, Spearman-Brown coefficient, and Guttman Split-Half coefficient were calculated.

Main Analyses Conducted on the Research Questions

To address the first two research questions and understand the data behavior and how primary school teachers responded to questionnaire items, providing an overview of response distributions and characteristics, descriptive statistical analysis was applied. Descriptive statistics were calculated for unidimensional data (mean, standard deviation, variance). To address the remaining two research questions and investigate relationships between factors, and to measure the degree of association between two factors or variables, Spearman correlation coefficient (ρ) was calculated.

3.1.3. Results

Preliminary Results at the Level of the Instrument Used

The Cronbach's Alpha reliability coefficient for the entire instrument (113 items) is .973, for the scale of selecting and processing animations it is .957, and for the scale of using animations in teaching activities it is .979. Values close to 1 indicate high internal consistency of the instrument and its two scales. Spearman-Brown coefficients for the scale of selecting and processing animations (.856) and for the scale of using animations in teaching activities (.923) suggest good internal consistency when the test length remains constant. Guttman Split-Half coefficients for the scale of selecting and processing animations (.856) and for the scale of using animations in teaching activities (.923) indicate that scores obtained from one half of the test are similarly consistent with those obtained from the other half, indicating good consistency between the two halves of the test. The internal consistency value for the questionnaire addressed to primary school teachers regarding the selection, processing, and use of animations shows statistically acceptable values, indicating that the instrument is suitable for further statistical analyses.

Main Results at the Level of Research Questions

Results Regarding the Selection and Processing of Animations for Teaching Activities

The results indicate that across all items or indicators, values range from the lowest mean of 2.46 to the highest mean of 4.75. Standard deviation ranges from the smallest value of 0.72, indicating a low data dispersion relative to the mean, to the largest value of 1.49, indicating high data dispersion relative to the mean. Variance values across all items or indicators range between 0.519 and 2.2.

Results Regarding the Use of Animation Films in Teaching Activities

Across all items or indicators, values range from the lowest mean of 2.62 to the highest mean of 4.11. Standard deviation ranges from the smallest value of 1.14, indicating low data dispersion relative to the mean, to the largest value of 1.53, indicating high data dispersion relative to the mean. Variance values range between 1.27 and 2.35.

Results Regarding Correlations between Factors Influencing the Selection and Processing of Animations for Teaching Activities

Table 3.1 presents the correlation matrix indicating relationships between variables or factors measured through the questionnaire addressed to primary school teachers regarding the selection and processing of animations. The values in each cell of the matrix represent the correlation coefficient between two factors. It is observed that all values are positive, suggesting that as one variable increases, the other tends to increase (and vice versa). The asterisks accompanying all values indicate that they are statistically highly significant at the 0.01 significance level. The data show that correlation coefficient values range between .420** and .735**, indicating moderate correlations between factors (range 0.5 - 0.9) and weak correlations between factors (range 0.1 - 0.5).

Table 3.1.

Correlations between Factors Influencing the Selection and Processing of Animations for Educational Activities.

	Source of the films	Internet and technology	Characteristics of the film	The teacher's purposes	Teacher's competence	Subject discipline	Learning content
Source of the films	-						
Internet and technology	.538**	-					
Characteristics of the film	.555**	.678**	-				
The teacher's purposes	.501**	.636**	.653**	-			
Teacher's competence	.448**	.638**	.620**	.682**	-		
Subject discipline	.435**	.444**	.571**	.615**	.507**	-	
Learning content	.420**	.430**	.560**	.562**	.488**	.655**	-
Student characteristics	.492**	.445**	.603**	.624**	.557**	.607**	.735**

Results Regarding the Correlations Between Factors Influencing the Use of Animation Films in Teaching Activities

Table 3.2 presents the correlation matrix indicating relationships between variables or factors measured through the questionnaire addressed to primary and secondary education teachers (PÎP) regarding the use of animations. The data show that the correlation coefficients range from .381** to .843**, indicating the presence of moderate correlations between factors (0.5 - 0.9 interval) and weak correlations between other factors (0.1 - 0.5 interval). All correlations are statistically very significant at the 0.01 level.

Table 3.2

Correlations Between Factors Influencing the Use of Animations in Teaching Activities

	Access to Technology	Purpose of Use	Timing of Viewing	Methods and Procedures	Students' motivation	Comprehension	Memorization	Teacher's and student's competence
Access to Technology	-							
Purpose of Use	.453**	-						
Timing of Viewing	.381**	.715**	-					
Methods and Procedures	.469**	.760**	.756**	-				
Students' motivation	.480**	.731**	.676**	.772**	-			
Comprehension	.538**	.728**	.683**	.767**	.843**	-		
Memorization	.457**	.670**	.587**	.694**	.767**	.828**	-	
Teacher's and student's competence	.410**	.735**	.597**	.709**	.740**	.761**	.788**	-

3.1.4. Discussions and Conclusions

From the analysis and interpretation of the statistical results, similarities in the opinions of Romanian teachers (PÎP) with those of future PÎP or science teachers, particularly from Turkey, are noted regarding certain investigated issues related to creating science animation films and their use in primary education at this discipline.

The study also reveals the alignment of many PÎP opinions with their own perceptions, views, and concepts regarding the preparation of animation films for science lessons and their utilization in primary education at this discipline. This alignment of opinions, along with identifying the challenges faced by PÎP on this subject, is useful for designing and conducting quasi-experimental research, selecting instructional models, methods, content, and animation films to use in experimental activities.

Regarding the survey participants, their large number contributed to ensuring the relevance and validity of the study, but the generalization of conclusions could be limited by the fact that opinions from some counties were not collected or were gathered from few participants.

3.2. Study 2: Models of Instruction Based on Animations. A Narrative Literature Review

3.2.1. Introduction

In the last two decades, teaching activities have increasingly promoted and utilized student-centered instructional models: the "Know – Want to know – Learn" model (Ogle, 1986), the "Engagement – Sense making – Reflection" model (Steel et al., 1998), and the pre-reading – reading – post-reading model (Pamfil, 2009). In science education, several discovery-based instructional models have been employed: the Exploration – Explanation – Extension model (Martin et al., 1998), the 5E Model (Bybee 2002, 2009). Dulamă et al. (2021) integrate animated films into many of these instructional models, adapting the "Know – Want to know – Learn" model, the "Engagement – Sense making – Reflection" model, the 5E Model, and others. Studies indicate that in science education, many instructional models are used to develop scientific thinking (e.g., the 5E model promoted by Bybee). The effectiveness of certain instructional models in science learning is tested, but their descriptions are often incomplete, lacking necessary information for practical application and comparison between instructional models. Many instructional models in use do not incorporate animated films.

Purpose and Research Questions

Building on the aforementioned observations, the purpose of our study is to identify and describe in the literature instructional models based on animations that are currently used or could be used in science education. Meta-analyses or other reviews on works addressing this subject have not been identified to date. The current review aims to establish the state of research in the field, rather than the size of the effect of animation-based instructional models, making narrative analysis the most suitable approach. The literature review aims to compile a comprehensive foundation of instructional models and relevant information to provide a comprehensive understanding of the advantages and disadvantages of using each instructional model in primary science education. The following research questions were formulated for this study:

(1) What are the instructional models or strategies based on animations used in science education in primary schools and investigated in studies?

(2) What are the stages described in studies that are followed in the application of instructional models or strategies based on animations in science education in primary schools?

3.2.2. Method

Several stages are followed in this study. In *the data collection stage* through internet search, the following steps are conducted: searching for studies related to the use of animated films in science education in primary schools, both within and outside databases, using specific keywords; refining the number of studies by adding specific terms to the search; searching for studies in relevant education databases.

In *the study selection stage*, studies were initially selected based on their title, keywords, abstract, and a brief overview of their content, and subsequently based on other criteria (author statements; description of instructional model or strategy stages by authors; mention of application of instructional model or strategy in primary science education; study participants are primary school students, teachers, or potential instructional personnel; teaching activities involve the use of an animated film or animation, or creating an animation for students; free access to the study.)

In *the data extraction stage*, relevant information for the study was selected. In the data processing stage, a content analysis and synthesis of each study were conducted (naming of instructional model attributed by researchers; categorization of the model; standardization of terms by researchers: use of stage designation, use of the acronym GE for experimental groups and GC for control groups, use of pre-test for the test administered before formative intervention and post-test for the one administered after formative intervention.) In the data presentation stage, essential information for each instructional model is included in data tables and circular schemes. Each model and its application method is described and explained in the study text, in the "Results" and "Discussion" sections.

3.2.3. Results

In the 12 selected studies, 20 instructional models, variants thereof, or instructional strategies were presented. These instructional models were grouped into seven categories: one category related to learning through animation production and six categories of instructional models involving learning through the use of animations: illustrative model, expository model, flipped classroom model, interactive model, discovery learning model, simulation-based learning model. The flipped classroom model includes six application variants. The interactive model comprises four models: Know-Want to know-Learn model; Evocation-Sense-Meaning-Reflection model; classroom model implementing animated film; Preview-View-Review model. The discovery learning model includes five instructional models: Explore-Explain-Extend model; 5E model; Animated heuristic branching model; Discovery learning model using animated media; Problem-based learning model using animated media.

3.2.4. Discussions and Conclusions

Globally, there are numerous studies on the use of animations in science education, but very few focus on primary education and even fewer rigorously investigate and describe the use of instructional models or strategies. This situation can be explained by the fact that instructional personnel, even though they apply certain instructional models in science lessons, have little interest in conducting and publishing scientific research.

Most studies are published in journals or volumes not indexed in relevant databases for educational research, but their quality (detailed, clear, rigorous descriptions) facilitates understanding of how instructional models are applied in practice, in the classroom, and their application in new contexts by other researchers or primary school teachers.

Regarding instructional models where science learning occurs through students creating animations, there is a weak connection to the official curriculum, and their implementation requires significant material and time resources (weeks or months), diverse skills (especially digital) from teachers and students. Regarding instructional models where learning occurs through watching animations or using interactive animations, there is a predominance of models centered on student activity (16 models or variants).

Regarding the number of stages, it is noted that this varies from three stages to six stages, but this variation is subjective and irrelevant because the order of performing certain activities in the learning process is more important than the order of stages. From the analysis of stage names, similarities are observed, indicating adaptation or development of previous models in new contexts, as well as conducting similar activities in those stages. Differences in stage names are also observed, although similar actions are performed by teachers and students in those stages. These differences indicate a weaker connection to literature in the field of educational sciences, but also that teachers intuitively design activities based on their experience and beliefs about science learning.

Regarding the timing of animation use, there are different conceptions among researchers. Regarding the place of viewing or using animations, it is observed that in the flipped classroom model, viewing can be done at home or at school. Regarding the evaluation stage, this was included in only three instructional models based on animations. Dulamă et al. (2021) include an evaluation stage at the end of all instructional models based on animations described, including those taken from other authors and adapted for multimedia use in science learning. The importance of assessing acquired knowledge in science learning activities is highlighted by Bybee (2002), who introduces the evaluation stage in the 5E model and recommends assessment throughout the learning process (Bybee, 2015).

Regarding the investigation of the effects of applying these instructional models, it is noted that they have not been tested in primary education, authors suggest testing them but do not provide free access to the multimedia products used, and international language is not consistently used in their texts.

3.3 Study 3: The Effect of Animated Films and Schematic Drawings on Students' Knowledge Acquisition in Science

3.3.1. Introduction

Learning through the observation of animated films and schematic drawings is based on visual perception. Globally, numerous studies have compared the effects of animations to static visual materials on learning outcomes. Most studies compare the effects of viewing different types of animations with those of static visual materials at university, high school, or middle school levels, with only three studies focusing on primary education (Chikha et al., 2021; Hapsari et al., 2019; Kanellidou & Zacharia, 2019).

Literature review reveals conflicting results and conclusions regarding the effectiveness of learning through animated films compared to learning through observing drawings. Meta-analyses and literature reviews often indicate biases favoring animations and influencing outcomes through teaching methods associated with viewing animated films or static visual materials. The lack of detailed descriptions of animated films and static visual materials used in studies, as well as limited access to these films and materials, hinder a thorough understanding of how their characteristics, including content, influence students' acquisition of knowledge in science. Based on these findings, this study aims to investigate the effects of animated films and schematic drawings on understanding and learning in science, under conditions minimally affected by bias.

Purpose, Variables, Hypotheses

The purpose of the research is to examine the effects of viewing animations on students' acquisition of knowledge in the field of science, compared to the effects of observing static visual materials (schematic drawings) and listening to oral texts with the same content.

The study variables are as follows: animation viewing (independent variable), observation of schematic drawings (independent variable), students' knowledge volume (number and accuracy of system components, processes, word-image correspondences, and element localizations) (dependent variable), and degree of stability of students' knowledge (dependent variable).

The following research hypotheses have been formulated:

I^1 – The volume of knowledge acquired by students after viewing animations is greater than after observing them in schematic drawings and listening to a text.

I^2 – The volume of knowledge acquired by students after revisiting animations is greater than after initial viewing.

I^3 – The volume of knowledge acquired by students after revisiting animations is greater than after re-observing them in schematic drawings and re-listening to a text.

I^4 – The stability of knowledge acquired by students after viewing animations is greater than after observing them in schematic drawings and listening to a text.

3.3.2. Method

Participants

The research was conducted in six schools in Sălaj County during the academic year 2021-2022, starting in October and concluding in January. Class selection was based on criteria related to teachers (being titular teachers, holding at least a teaching degree II, having digital competence, voluntary participation, informed consent), after-school activity organization, total number of students in the class, student acceptance, and parental consent for their children's participation in the study. Student selection was based on their enrollment in a specific school and class. The study involved 128 third-grade students, with an average age of 9 years, of both genders. Experimental groups (GE1 and GE2) were formed based on students' results from an initial test administered in October 2021. Each experimental group consisted of 64 students. The research ensured confidentiality of students' and teachers' personal data and complied with legal and ethical requirements specified in GDPR.

Procedure

The students from both experimental groups participated in three activities over the course of three weeks in the "Natural Sciences" subject, addressing three themes: "The Solar System," "Rotational Motion," and "Revolutionary Motion." These activities were organized by the classroom teachers based on a lesson plan provided by the researcher. They took place outside regular class hours, during after-school activities, and each session lasted for 60 minutes.

Each activity for each experimental group comprised 3 stages conducted on the same day: the pre-experimental stage - administering the pre-test (10 minutes); the first formative intervention stage (15 minutes); the first post-experimental stage - administering post-test 1 (10 minutes); the second formative intervention stage (15 minutes); the second post-experimental stage - administering post-test 2 (10 minutes). Eight weeks after the fourth experimental activity, a re-test was administered as part of the re-testing stage.

Didactic Activities

For the formative intervention in GE1, two animated films were selected: "Paxi – Solar System" (ESA, 2016) and "Paxi – Day, Night, and Seasons" (ESA, 2017) from the European Space Agency. In each activity, for each theme, after administering the pre-test, students in GE1 watched the animated film projected on a screen with a video projector, while students in GE2 observed the schematic drawing projected on the screen and listened to the text of the animated film read by the teacher. After administering post-test 1, students in GE1 reviewed the animated film twice, whereas students in GE2 re-observed the schematic drawing projected on the screen and listened to the text of the animated film read by the teacher once more. The activity concluded with the administration of post-test 2.

Instruments

Data collection for evaluating students' knowledge was conducted through several knowledge tests designed by the researchers: an initial test, 3 pre-tests, 6 post-tests, and a re-test. Each instrument allowed for a maximum score of 10 points, with no bonus points awarded. Scores were recorded for each participant individually. Data about the animated films were analyzed using an Animation Analysis Form developed by the researchers, which includes three categories of data related to animations: general information, production characteristics, and auditory and visual characteristics.

Data Analysis

Preliminary Analyses – Initial Test Level To test the equivalence of the two experimental groups, comparative statistical analyses were conducted. For both groups, the mean and standard deviation were calculated. To assess whether the difference between the two groups is statistically significant, the independent samples t-test was used.

Main Analyses – Testing Hypotheses

ANOVA analyses were conducted using pre-test results as a covariate. The Tukey post-hoc test was used to determine if there are significant differences between the three experimental phases (pre-test, post-test 1, and post-test 2) for each of the two experimental conditions (watching the film and observing the drawings) across the three themes. The t-test was used to establish whether there are statistically significant differences between GE1 and GE2 across experimental phases. Results are expressed in terms of mean differences, and F and p values indicate the level of significance of these differences.

Secondary Analyses – Verbal Data Content

The text of the animated films used in the study underwent content analysis and interpretation. The following steps were followed: viewing the animated film and listening to the text; transcribing the text of the animated film; establishing categories of analyzed aspects; establishing criteria for comparing animated films; extracting information from the written text and including it in comparative data tables; interpreting the collected data.

Secondary Analyses – Visual Data Content

The animations were analyzed using the "Animation Analysis Form." The drawings observed by students in GE2 were analyzed using visual methods. Three categories of data were identified: aspects from the text correctly represented in the drawings, aspects incorrectly represented in the drawings, aspects from the text not represented in the drawings.

3.3.3. Results

Preliminary Results – At the Initial

Test Level At the initial test level, the data show that the results of the two experimental groups are close: GE1 ($M = 8.78$); GE2 ($M = 8.64$). The standard deviation is small for GE1 ($SD = 0.99$) and larger for GE2 ($SD = 1.73$). The small t-value (0.07) indicates that the difference between the groups is small. The high p-value ($p = 0.94$) indicates that the difference between the two groups is not statistically significant at the 0.05 and 0.01 significance levels. The analysis of the results shows that there are no significant differences between the two groups.

Main Analyses – Hypothesis Testing

The results confirm all hypotheses. At the mean level, for GE1, the ANOVA analysis shows a statistically significant increase in means ($p = .00$) and a larger volume of knowledge across all three topics after viewing each animation film, as well as after revisiting each animation film. At the mean level, for GE2, the ANOVA results show a statistically significant increase in means ($p = .00$) and a larger volume of knowledge in two topics ("Solar System" and "Revolutionary Movement") after observing schematic drawings, as well as after re-observing them. The ANOVA results indicate a greater effect on the volume of students' knowledge after viewing each animation film and revisiting each film compared to the effect on the volume of students' knowledge after observing schematic drawings and re-observing them.

At the mean level, the T-test results show at the re-test, for GE1, an increase in the mean and a larger volume of knowledge across the three topics. For GE2, the T-test results show at the re-test a decrease in the mean compared to post-test 2 and a smaller volume of knowledge compared to both post-test 2 and GE1. The differences between the results of the two groups at the re-test are statistically significant. The results indicate a higher degree of stability in knowledge after viewing and revisiting animation films compared to observing and re-observing schematic drawings.

The results of the Post-hoc Tukey test, for both GE1 and GE2, show no statistically significant differences ($p = .00$) across all phases and topics. The Post-hoc Tukey results indicate that the effect of viewing animation films was small on the outcomes of students in GE1, whereas in GE2, the effect of observing schematic drawings was smaller across multiple phases compared to GE1.

3.3.4. Discussions and Conclusions

Discussions Regarding Hypothesis Testing Although at the mean level, the results indicate greater effects of watching animation films compared to observing schematic drawings on students' knowledge across the three topics, the significance level of the differences varies between certain phases within each group and across groups.

To avoid numerical bias, where "many static images are simultaneously compared with a single animation" (Castro-Alonso et al., 2016, p. 239), each group included in our study was exposed to a single visual representation (one animation vs. one schematic drawing). Our findings indicate numerical bias for GE1 because each animation film comprised multiple images, thereby providing students in this group with a greater volume of visual information compared to students in the group that observed a schematic drawing. To mitigate numerical bias, GE2 should indeed observe more schematic drawings. The number of these schematic drawings for the second group should be determined based on the number of "scenes" represented in the animation film. We consider it inappropriate to generalize that observing a specific number of schematic drawings benefits learning more than observing another number, compared to viewing a dynamic representation.

Another relevant aspect in comparing the learning effects of watching animations versus observing schematic drawings is the ratio of images per time. Students in GE2 benefited from observing a static image, whereas students in GE1, within the same time interval, observed multiple dynamic images, thus their cognitive load was much higher. This ratio can be improved by increasing the number of schematic drawings intended for observation by GE2 students, ensuring user control in viewing animations, or by slowing down the presentation rate of relevant images from the animation. The application of these latter solutions assumes a reduction in the "fleeting" effect of images in animation films.

The fact that students had prior knowledge of the three topics may have influenced higher scores in some items of the post-tests. The results of the post-tests and re-tests provide evidence that students predominantly acquired declarative knowledge as a result of watching animation films and observing schematic drawings.

Future research directions suggest involving groups with different levels of prior knowledge in the initial test (non-equivalent groups) or in pre-tests (one group with low scores, one with medium scores, and one with high scores) to investigate the relationship between prior knowledge and understanding of the content of animation films. It is recommended to use films with unfamiliar themes for students, testing all information conveyed through the animation film, and separately testing static information from that which concerns the dynamics of entities, phenomena, and processes.

3.4. Study 4: Effects of Using the Flipped Classroom Model, Based on Animation Films and Study Guide, on Students' Knowledge Acquisition in Science

3.4.1. Introduction

In the literature, flipped classroom is defined as a blended learning approach where students learn content by watching videos at home and actively engage in class through discussions on complex concepts, answering questions related to the content (Stone, 2012), applying what they have learned (Bergmann & Sams, 2012), solving problems, and learning cooperatively (Tucker, 2012). The flipped classroom model has been used in educational programs at various levels, from elementary school to undergraduate programs (Schmidt & Ralph, 2016). At the primary education level, we analyzed five studies that utilized the flipped classroom model and videos.

From the literature analysis, multiple variations of the flipped classroom model are found to have beneficial effects on students and learners. Some studies highlight the risk that students may not read or watch the videos at home before the lesson, and also criticize the absence of describing activities conducted after those performed in class with the teacher, as well as the lack of detailed information about evaluation. In our study, we aim to address these issues identified in the literature and apply the flipped classroom model in a way that ensures increased learning efficiency in science through the use of animation films.

Purpose, Variables, Hypotheses

The purpose of our research is to study the effects of using animation films within the flipped classroom model and study guide on students' knowledge acquisition in science, compared to the effects of using animation films within the flipped classroom model without a study guide.

The variables of our study are as follows: independent variable: Viewing animation accompanied by the study guide before the lesson, dependent variable: Volume of students' knowledge (number and correctness of knowledge), dependent variable: Stability of students' knowledge.

Here are the research hypotheses that have been formulated:

I^1 – Watching the animation with a study guide before the lesson leads to a greater increase in the volume of students' knowledge compared to watching the animation without a study guide before the lesson.

I^2 – Watching the animation with a study guide before the lesson, followed by classroom discussions based on the animation, results in a greater increase in the volume of students' knowledge compared to watching the animation before the lesson with a study guide.

I^3 - Watching the animation without a study guide before the lesson, followed by classroom discussions based on the animation, leads to a greater increase in the volume of students' knowledge compared to watching the animation without a study guide before the lesson..

I^4 - Watching the animation with a study guide before the lesson, followed by classroom discussions based on the animation, results in a greater increase in the volume of students' knowledge compared to watching the animation without a study guide before the lesson, followed by discussions based on the film.

I^5 - Watching the animation with a study guide before the lesson, followed by classroom discussions, increases the stability of students' knowledge more than watching the animation without a study guide before the lesson, followed by classroom discussions.

3.4.2. Method

Participants

The research was conducted in six schools from Sălaj County during the 2021-2022 school year, in the months of February-April. The selection of schools, classes, and students followed the same procedure as in Study 3. Each experimental group (GE1 and GE2) consisted of 69 students.

Procedure

Students from both groups participated in four teaching activities conducted over four weeks in the "Natural Sciences" subject. The teaching activities were organized by classroom teachers based on lesson plans provided by researchers and took place outside regular class hours, as part of After school activities. Each activity consisted of six stages. The first five stages of each teaching activity were conducted over two consecutive days. The re-testing stage was conducted four weeks after the fifth stage.

Teaching Activities

For the experimental teaching activities based on animated films, four themes were selected: "Melting", "Solidification", "Evaporation", and "Condensation", included in the "Mathematics and Environmental Exploration Curriculum, Grade II" (MEN, 2014). GE1 conducted the activities outlined in Table 3.1. GE2 participated in the same activities, but without using the study guide.

Table 3.3

Stages and Activities Implemented in the Flipped Classroom Instruction Model

Day	Stage	Activities and durations
The first day	Pre-experimental	– Administering the pre-test (10 minutes)
	Formative Intervention 1	– Classroom activities: class discussions on the subject, objectives, tasks (15 minutes) – Pre-class activities (at home): watching the animation and completing the study guide tasks (variable duration for each student).
The second day	Post-experimental 1	– In-class activities: administering post-test 1 (10 minutes)
	Formative Intervention 2	– Classroom activities: - whole-class discussions (20 minutes); - individual activities - completing worksheets (2 minutes); - group activities - problem-solving (15 minutes)
	Post-experimental 2	– Administering post-test 2 (10 minutes)
The third day	Post-experimental 3 (re-testing)	– Administering the re-test (10 minutes)

Instruments

The data collection required to assess students' knowledge was conducted using multiple knowledge tests designed by the researcher: an initial test, 4 pre-tests, 8 post-tests, and 4 re-tests. Each instrument allowed a maximum score of 10 points, with no points given by default. Scores were generated for each participant. For each of the four animations, a study guide was developed containing 4-6 questions.

Data Analysis

Preliminary Analyses Conducted at the Initial Test Level

Statistical comparative analyses were conducted to test the equivalence of the two experimental groups. Mean and standard deviation were calculated for both groups. The independent samples t-test was used to evaluate whether the difference between the two groups is statistically significant.

Main Analyses – Testing Hypotheses

ANOVA analyses were performed using pre-test results as a covariate. The Tukey post-hoc test was used to determine if there were significant differences between the four experimental phases (pre-test, post-test 1, post-test 2, and re-test) for each of the two experimental conditions (Viewing animation with study guide vs. Viewing animation without study guide) across the four themes. The t-test was used to establish whether there were statistically significant differences between GE1 and GE2 across experimental phases. Results are expressed in terms of mean differences, and F and p values indicate the significance level of these differences.

Secondary Analyses - Verbal and Visual Data Content

The text of the animations used in this study underwent quantitative content analysis and interpretation. The questions from the study guides underwent qualitative content analysis. Based on the analysis of the questions, the role or function of each question was determined. These functions of the questions are correlated with the functions of the text in the animations and aim to ensure that the function of the text and the associated visual information were fulfilled. The animations were analyzed using the "Animation Film Analysis Sheet",

3.4.3. Results

Preliminary Results - At the Initial Test Level

At the initial test level, the means of the two groups are close: GE1: $M = 8.78$; GE2: $M = 8.64$. The standard deviation is small for GE1 ($SD = 0.99$) and larger for GE2 ($SD = 1.73$). The low t-value (0.07) indicates a small difference between the groups. The high p-value ($p = 0.94$) shows that the difference between the two groups is not statistically significant at the 0.05 and 0.01 significance levels. The analysis shows that there are no significant differences between the two groups.

Main Results - Testing Hypotheses

Regarding the first hypothesis tested in this study, statistical results demonstrate that the use of the flipped classroom model, where students watch animations and complete study guides before class at home, is more effective in increasing students' knowledge volume compared to watching animations without study guides before class (Hypothesis 1). The statistical results also demonstrate that class discussions with the teacher lead to increased knowledge volume compared to watching animations before class, both with (Hypothesis 2) and without (Hypothesis 3) using study guides, with a greater effect observed for students using the study guide (Hypothesis 4). The use of the study guide, combined with animation viewing and in-class discussions, also contributes to increased knowledge stability among students (Hypothesis 5).

3.4.4. Discussions and Conclusions

A vulnerable point of this instructional model is the risk that students may not watch the animations at home or may not complete the assigned tasks. This risk is higher for students in higher education levels or for college students, due to several reasons: students may not have sufficient time resources to complete tasks; they may postpone task completion if given the option by the teacher; they may be extrinsically motivated (not attributing grades). In primary education, most students complete assigned tasks as homework, particularly because they receive daily homework assignments that teachers systematically and rigorously check lesson by lesson.

In the context of this model, the study guide is an essential and valuable tool that serves as a static cognitive scaffold guiding students' "understanding" of concepts represented in the animation. The study guide acts as a static scaffold incorporated into the learning environment, requiring students to pay increased attention to the assigned task (watching the animation) and acts as an affective scaffold encouraging students to concentrate and persevere with the task. For the study guide to fulfill these functions, teachers should check and discuss with students how they completed the tasks and provide constructive feedback.

Regarding animations, for students to watch them at home, they should be interesting to stimulate curiosity and be age-appropriate and suitable for their level of understanding and knowledge. In cases where students are asked to watch an animation they do not understand due to lack of prerequisite knowledge, there is a risk they will abandon watching and completing tasks because they perceive them as too difficult.

3.5. Study 5: The Effect of Narrative Animation Films and Schematic Drawings on Students' Acquisition of Science Knowledge

3.5.1. Introduction

Based on the literature review, it is noted that there are no studies regarding the use of visual narratives, animation films for children in science learning in primary education. Our study is based on two important findings: children watch and rewatch many animation films for children; children enjoy watching and rewatching animation films for children very much; these films offer a lot of science information that children implicitly assimilate in a pleasant way. Our research starts from the idea that, during the viewing of animation films for children, they predominantly receive and store narrative-specific information in long-term memory and pay little attention to science-specific information.3.5. Studiul 5: Efectul Filmelor de Animație Narative și a Unor Desene Schematice Asupra Dobândirii Cunoștințelor Elevilor, la Științe

Purpose, Variables, Hypotheses

The purpose of the research is to study the effects of children watching animation films on their acquisition of science knowledge, compared to the effects of observing similar drawings and listening to oral texts with the same content.

The study variables are as follows:independent variables: Watching the animation film, observing drawings (film captures), listening to the text of the animation film, dependent variables: Students' knowledge volume (number of specific information about the subject of the animation film), degree of stability of students' knowledge, specific science inferences based on the animation film, specific narrative inferences based on the animation film**.**

Here are the research hypotheses formulated:

I^1 – The volume of knowledge acquired by students through watching the animation film is greater than that acquired through observing drawings (film captures) and listening to the text of the animation film.

I^2 – The volume of knowledge acquired by students through watching the animation film is greater than that acquired through listening to the text of the animation film.

I^3 – The volume of knowledge acquired by students through watching the animation film and discussing based on the film is greater than that acquired through observing drawings (film captures) and listening to the text of the animation film.

I^4 – The volume of knowledge acquired by students through watching the animation film and discussing based on the film is greater than that acquired through listening to the text of the animation film.

I^5 – The degree of stability of knowledge acquired by students through watching the animation film and discussing is greater than that resulting from observing drawings (film captures) and listening to the text of the animation film.

I^6 – The degree of stability of knowledge acquired by students through watching the animation film and discussing is greater than that resulting from listening to the text of the animation film.

I^7 – The volume of narrative-specific knowledge acquired by students through watching the animation film is greater than the volume of science-specific knowledge.

I^8 – The volume of narrative-specific inferences made by students through watching the animation film is greater than the volume of science-specific inferences.

I^9 – The volume of narrative-specific knowledge acquired by students through watching the animation film is greater than the volume of narrative-specific knowledge acquired through observing drawings (film captures) and listening to the text of the animation film.

I^{10} – The volume of science-specific knowledge realized by students through watching the animation film is greater than the volume of science-specific inferences made through observing drawings (film captures) and listening to the text of the animation film.

I^{11} – The volume of narrative-specific inferences made by students through watching the animation film is greater than the volume of narrative-specific inferences made through observing drawings and listening to the text.

I^{12} – The volume of science-specific inferences made by students through watching the animation film is greater than the volume of science-specific inferences made through observing drawings and listening to the text.

I^{13} – The volume of narrative-specific knowledge acquired by students through watching the animation film is greater than the volume of narrative-specific knowledge acquired through listening to the text of the animation film.

I^{14} – The volume of science-specific knowledge realized by students through watching the animation film is greater than the volume of science-specific inferences made through listening to the text of the animation film.

I^{15} – The volume of narrative-specific inferences made by students through watching the animation film is greater than the volume of narrative-specific inferences made through listening to the text.

I^{16} – The volume of science-specific inferences made by students through watching the animation film is greater than the volume of science-specific inferences made through listening to the text.

3.5.2. Method

Participants

The research was conducted in six schools in Sălaj County during the academic year 2021-2022, in the months of May and June 2022. The selection of schools, classes, and students followed the procedures outlined in Study 3. Each experimental group (GE1, GE2, GE3) consisted of 44 students.

Procedure

Students from the three groups participated in three activities ("Bambi", "The Jungle Book", "The Little Mermaid") conducted over the course of one week in the subject of "Natural Sciences". The activities were organized by the classroom teachers based on an activity project provided by the researchers, outside of regular class hours, during After school activities, and lasted for 3 hours each. Each activity included 5 stages conducted on the same day: the pre-experimental stage - administration of the pre-test (20 minutes); formative intervention 1 stage (approximately 1 hour and 25 minutes); post-experimental 1 stage - administration of post-test 1 (20 minutes); formative intervention 2 stage (60 minutes); post-experimental 2 stage - administration of post-test 2 (20 minutes). The re-testing stage - administration of re-tests - took place 4 weeks after the formative intervention. Each re-test (20 minutes) was administered on one day of the week.

This methodological approach was designed to assess the effects of viewing and discussing animated films on students' acquisition of knowledge in natural sciences, compared to other teaching methods used in a similar context.

Teaching Activities

Learning activities based on animated films were associated with two themes outlined in the "School Curriculum for Mathematics and Environmental Exploration, Grade II" (MEN, 2014): "The Forest" and "The Black Sea." For the formative intervention in GE1, three animated films were selected: "Bambi" (Disney & Hand, 1942), "The Jungle Book" (Disney &

Reitherman, 1967), "The Little Mermaid" (Clements & Musker, 1989). For GE2, three homonymous books were selected, each containing 63 illustrations and text similar to that in these films. For GE3, the content sample consisted of the text presented in the books used in GE2. The animated films and book illustrations depict plants and animals from deciduous and coniferous forest environments ("Bambi"), from tropical rainforest environments ("The Jungle Book"), and from the planetary ocean environment ("The Little Mermaid").

After administering the pre-test, in the first formative intervention phase, students in GE1 watched the animated film, students in GE2 observed the projected illustrations on a screen and listened to the text from the book read by the teacher, while students in GE3 listened to the text from the book read by the teacher. After the first post-test, in the second formative intervention phase, each GE group participated in a discussion focused on analyzing the narrative (characters, actions) and the visual and textual representation of the living environment (plants, animals, environmental conditions). The teacher asked students questions to deduce information (inferences) based on the content of the animated film and the book. The teacher organized a scheme on the board with specific scientific information, which students transcribed into their notebooks. The scheme included essential information about the characteristics of the environment presented in images and text. The activity concluded with the administration of the second post-test, followed by three re-tests after 4 weeks.

Instruments

Data collection necessary for evaluating students' knowledge was conducted through multiple knowledge tests designed by the researcher: an initial test, 3 pre-tests, 6 post-tests, and 3 re-tests. The maximum score that can be obtained is 10 points for the initial test and 20 points for the subsequent tests. No points were awarded automatically. Scores were generated for each participant.

Data Analysis

Preliminary Analyses - Initial Test Level

To test the equivalence of the three experimental groups, comparative statistical analyses were conducted. The mean and standard deviation were calculated for each of the three groups. Tukey's post-hoc test was used to determine if there were statistically significant differences between the three groups (GE1, GE2, and GE3) when compared pairwise at the initial test. Q value and p value were calculated.

Main Analyses - Testing Hypotheses

ANOVA analyses were conducted using pre-test results as a covariate. Tukey's post-hoc test was used to determine if there were significant differences between the four experimental phases (pre-test, post-test 1, post-test 2, re-test) for each of the three experimental conditions (Watching the animated film; Observing drawings and listening to text; Listening to text) across the three animated films. Tukey's post-hoc test was used to determine if there were statistically significant differences between the three groups compared pairwise across experimental phases. Results are expressed in terms of mean differences, with F values and p values indicating the significance level of these differences.

Secondary Analyses - Verbal and Visual Data Content

The text from the books used in the study, which is similar to that in the animated films, underwent content analysis and interpretation. The animated films were analyzed using a "Animated Film Analysis Sheet" developed by the researcher.

3.5.3. Results

Preliminary results at the initial test level show that the means of the three independent groups are close: GE1 - 8.79; GE2 - 8.44; GE3 - 8.79. The standard deviation is also similar across the three groups: GE1 (SD - 0.98), GE2 (SD - 1.29), GE3 (SD - 0.98). The p-value indicates that the differences between GE1 and GE2, GE1 and GE3, and GE2 and GE3 are not statistically significant, therefore the groups are equivalent and can be used in the quasi-experimental study. The main results show that all tested hypotheses were confirmed.

3.5.4. Discussions and Conclusions

Hypothesis testing was conducted within the context of three instructional models: the model based on watching animated films and discussing with the teacher; the model based on observing drawings and listening to text; the model based on listening to text. In the formative interventions where instructional models involving watching animated films or observing drawings were applied, observation method and multimodal learning were used, while in the model based on listening to text, receptive learning was emphasized. The results indicate that students who benefited from the instructional model based on watching animated films and discussing with the teacher had the most favorable learning conditions compared to the other groups.

Hypothesis testing was conducted in the context of children watching animated films, which are produced for commercial and artistic purposes rather than educational ones, and illustrated books containing screenshots and texts similar to those in the films. The results indicate that students benefited more from specific narrative information from visual narratives in films or illustrations in books than from specific scientific information represented visually or presented in text.

For perceiving, understanding, and memorizing specific scientific information provided by children's animated films, they generally need support from adults and teachers, especially. The results show that students benefited more from specific scientific information after discussions with teachers, indicating their need for cognitive scaffolding to place their own cognitive development within their proximal development zone.

Overall, the statistical analyses and results obtained in this study confirm all the hypotheses tested, demonstrating that watching children's animated films is more effective in increasing the volume of narrative-specific knowledge, inferences, and stability of narrative-specific knowledge than in increasing the volume of scientific knowledge, inferences, and stability of scientific knowledge. To avoid bias, all three groups listened to a similar text; however, the group that watched animated films benefited more from visual information than the other groups.

CHAPTER IV. CONCLUSIONS

4.1. Conclusions Regarding the Relationship between Theoretical Premises and Practical Application

Based on the extensive and in-depth literature analysis, it was found that there is a wide variety of animations or animated films used in research in educational sciences and other scientific fields (physics, chemistry, biology, among others), which has led to a diversity of conclusions regarding their effectiveness in learning. To clarify the differences between various types of animations or animated films, they were classified based on specific criteria, the identified categories were described, and synthesized into a scheme. Identifying the essential attributes of animations and describing the types of animations was necessary and useful in selecting animated films with different characteristics for use in quasi-experimental studies, analyzing and interpreting the results, and gaining a deep understanding of the effects of these animated films on science learning.

From a theoretical perspective, numerous theories worldwide attempt to explain how learning occurs through animated films as multimodal products. Although the identified theories relate to multimodal learning in general, it was observed that teaching and learning in sciences are built and supported according to these theories, thereby providing the foundation upon which experimental activities were designed and implemented.

Understanding the typology of animated films and the theories supporting learning through watching these films contributed to the selection of animated films with different characteristics for use in quasi-experimental research and to test their effectiveness in science learning. Educational animated films were chosen for Study 3, animated films were taken from a school textbook for Study 4, and children's animated films—artistic films offering a narrative—were viewed by students in Study 5.

Theoretical studies and other scientific papers describe various didactic strategies and instructional models aimed at teaching and learning sciences through animated films. Building upon these instructional models and leveraging theories supporting multimodal learning, the experimental activities designed and implemented were originally structured into several stages. These explicitly detailed the organization forms of the activity, the actions and roles fulfilled by teachers and students, the teaching methods and procedures applied in each stage, the cognitive processes performed by students, the evaluation tools and methods, and other information facilitating the implementation of these instructional models in practice and in experimental research.

Analysis of previous research conducted worldwide, grounded in diverse theories, provided insights into issues identified by researchers both in creating animated films and using them in various educational contexts. Literature review reveals diversity in qualitative and quantitative research on the use of educational animated films, as well as in science learning. Deep reading indicates that research results are influenced by bias in favor of animated films, as well as by certain methodological problems. Therefore, in our studies, we sought to avoid repeating mistakes highlighted in meta-analyses and other comparative studies and to test hypotheses in experimental contexts with instruments allowing precise measurement of the effects of animated films on student outcomes.

4.2. Conclusions Regarding the Achievement of Research Objectives and Hypothesis Confirmation

At the end of the research, the achievement of research objectives and the confirmation of hypotheses formulated in all quasi-experimental studies were noted.

4.3. Thesis Implications

Theoretical Implications

The first relevant theoretical implications of the thesis concern the concept of animated film presented in the first chapter. A range of concepts used in the literature in relation to animated films is highlighted, essential attributes of the animation or animated film concept are selected and clarified, and a detailed description of these attributes is provided. Animated films are classified based on 24 criteria, and the characteristics of films in these categories are described. The classification of animated films is represented in an original, synthetic tree-like scheme.

Study 1 is the first to explore the perceptions of primary and lower secondary school teachers about the factors influencing their choice and processing of animated films for use in teaching and learning sciences. Another innovative aspect is the grouping of these factors into categories and the analysis of correlations existing between these categories.

Study 2 is the first to describe instructional models, their variations, or instructional strategies using animated films in science learning in primary education. A theoretical novelty is the systematic, rigorous, and unified description of instructional models identified in the literature, adhering to a set of rules and principles, to provide teachers and other interested parties with pertinent information. The theoretical consistency of this study's contributions is ensured by establishing categories of instructional models, including several instructional models using animated films in each category, synthesizing these models into data tables facilitating comparison of stages and activities performed in applying each model, and visually representing them in diagrams.

Studies 3, 4, and 5 have several theoretical implications in science education. The theoretical contribution lies in the conception and application of multiple instructional models in which the main activity is watching an animated film: the model of instruction based on viewing and revising the animated film; the model of instruction based on observing and re-observing schematic drawings (Study 3); the flipped classroom model based on animated films and study guides; the flipped classroom model based on animated films without a study guide (Study 4); the model of instruction based on viewing animated films and discussing with the teacher; the model of instruction based on observing drawings and listening to a text; the model of instruction based on listening to a text (Study 4).

Methodological Implications

In the studies conducted and presented in this thesis, we were interested in improving several procedures and increasing their efficiency. Considering the population of primary and lower secondary school teachers and their distribution across the country, Study 1 provides a method of voluntary involvement of teachers in responding to questionnaires, named the "snowball" method, and brings an efficient method of data collection through an original instrument created where each item was associated with a Likert scale from 1 to 5.

Studies 3, 4, and 5, which are organized similarly, have several methodological implications. Firstly, to ensure the natural conduct of researching the effects of watching animated films, experimental activities were organized in classes and also at students' homes. Students participating in the study were selected based on their belonging to a class of students and a school. To test hypotheses and ensure the consistency of the research, within each study, three or four distinct experimental activities were conducted, each with a different theme allowing the viewing of an animated film, and all formative interventions were similarly organized in all classes of an experimental group.

To ensure the correctness of the investigations, in each study, the experimental activity was rigorously designed, the stages planned for each activity were described in chronological order, specifying the conditions, material resources, and time. To avoid differences in the amount of information provided to experimental groups through animated films and through texts, all groups heard the oral text from the animated film, regardless of whether they watched the animated film or not. Also, to avoid bias, in each study, the dialogue between the teacher and the students was similar, with teachers being provided with texts and scenarios with the dialogue imposed by the researcher.

Fourthly, to ensure accurate measurement of results, in each test administered in each class, teachers were given a grading key that included correct or acceptable answers, as well as the score allocated for each item.

Practical Implications

This thesis has several practical implications. The rigorous, systematic, and detailed description of instructional models and their visual representation in circular diagram schemes in Study 2 provides teachers, researchers, and other interested parties with essential information needed for a deep understanding of the didactic process and for explaining the effects on student outcomes, as well as for applying these instructional models in other educational contexts.

The coherent and chronological presentation of activities carried out in each study in text and in data tables facilitates comparison of experimental activities performed in research-involved groups, noting differences between formative interventions (independent variables) and allowing the replication of activities by other teachers or researchers in science learning or other educational disciplines.

Original materials (questionnaire, pre-tests, post-tests, re-tests, animated film analysis sheet, lesson plans, instructional model diagrams, study guides) designed and applied during this research, as well as multimodal (animated films) and visual materials (drawings), can serve as benchmarks for teachers and researchers interested in applying them in the classroom or conducting identical or similar research.

The presentation of factors influencing the choice, preparation, and use of animated films in science learning provides consistent benchmarks for comparing with personal opinions and for choosing such multimedia products based on scientific criteria for use in student activities or experimental research.

Defining the concept of animated film, classifying animated films, and describing various types of animated films, explaining the learning process accomplished through multimodal texts, and other theoretical aspects provide teachers with relevant benchmarks for successfully designing and implementing teaching activities in science education.

4.4. Limitations and Future Research Directions

In Study 1, in collecting teachers' opinions using a questionnaire, a research limitation could be the construction of responses by the researcher and the assignment of scores from 1 to 5, depending on the researcher's own vision and experience in selecting, processing, and using animated films in teaching activities in primary education. Other limitations could be: measuring personal opinions, which are subjective; not collecting teachers' opinions from some counties; not differentiating results based on participant characteristics (studies, classroom experience or seniority, teaching degree, etc.); influencing the analysis and interpretation of data by the subjectivity of the teacher-researcher. At the end of the study, several directions for future research are outlined: using this questionnaire in other studies at international or national levels; deepening aspects investigated in this study by dividing parts of the questionnaire and refining selected items; collecting opinions about other types of films, at other levels and in other educational disciplines.

For Study 2, a limitation could be that many of the instructional models presented in the literature have not been tested, so their effectiveness is debatable. Studies 3, 4, and 5 have similar limitations: the sample size of students, the sample of content, and the number of activities included in the formative intervention; the characteristics of each animated film viewed by students. The results obtained, their analysis, and interpretation have allowed us to draw relevant conclusions about the effects of viewing animated films for children on science learning in primary education.

The rigorous description of the conduct of this research and the materials used, included in the appendices of the thesis, enable the replication of activities and research among other groups of students from various backgrounds. Understanding that animated films are created with specific objectives in mind, PÎP should select those that provide the most conducive context for science education.

4.5. General Conclusions

At the PÎP level, our study demonstrates the interest of teachers in Romania in using animated films for science education, employing a wide array of methods, strategies, and educational techniques for this purpose. However, they also face challenges such as significant time resources required for searching and preparing films, access to equipment and the internet, and competence in using applications to enhance films. The decision of PÎP to use animated films in science education and the quality of their use are influenced by access to technology and the internet, digital competence in science and science education, as well as personal beliefs regarding the importance of viewing these films and the availability of resources to achieve this goal.

All our studies indicate that students acquire a greater volume of knowledge in the field of science after viewing animated films, which vary in their characteristics; however, statistical significance was not observed in all cases. In the case of animated films for children, which predominantly feature narrative content, the effect is stronger on the volume of knowledge and inferences specific to storytelling rather than those specific to sciences.

The results indicate that viewing and revisiting animated films contribute to increasing the volume of knowledge. Yet, to ensure understanding of processes and phenomena in the field of science, primary school students require support from PÎP with advanced skills in science and science education.

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