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MULTIMEDIA LEARNING THROUGH ONLINE MATHEMATICS EDUCATION IN ELEMENTARY AND SECONDARY SCHOOLS TO REDUCE COGNITIVE LOAD

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ABSTRACT. Due to the COVID-19 pandemic, the transition to online teaching has posed numerous challenges, particularly in mathematics education, which requires active interaction between teachers and students, as well as task demonstrations and feedback. Mathematics teachers and professors have attempted to adapt their methods to improve understanding of the material, reduce the burden of less critical content, and enhance concentration and retention of new information. This paper explores how cognitive learning and cognitive load theory can help improve online mathematics instruction through the use of well-designed multimedia educational content. According to cognitive load theory, learning is limited by the capacity of working memory, which must have enough space to process information and build long-term knowledge structures. Additionally, this paper examines ways to reduce working memory overload and emphasizes the importance of well-designed multimedia content for effective mathematics learning. Connecting mathematics to everyday life and using multimedia techniques can increase student interest and engagement, while excessive use of certain methods may lead to monotony and boredom.

1. INTRODUCTION

Due to the Coronavirus pandemic, we were forced to transition to online teaching. Students with online mathematics classes had the most difficulties. Since mathematics lessons require dialogue between teachers and students, demonstration of task-solving techniques, and feedback on comprehension, students of all ages encountered difficulties, particularly those in elementary schools. Students have struggled with understanding mathematical concepts since early grades, and these challenges became more pronounced during online classes. Teachers implemented various methods to conduct online mathematics classes, aiming to improve understanding of the material, reduce cognitive load from less essential content, and enhance concentration and retention of new material, often integrating it with previously learned concepts.

In this paper, we will explain what cognitive learning is, the principles of cognitive load theory, and how online mathematics education can be enhanced using multimedia educational materials.

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It is crucial for teachers to carefully plan their presentations so that students can easily grasp the educational content. Understanding the material involves not only comprehending key concepts but also establishing connections between these concepts and previously acquired knowledge, and applying them in tasks. According to cognitive load theory, learning is limited by the capacity of working memory, where acquired information must be stored while leaving enough space for processing in order to form personal knowledge structures within specific areas in long-term memory. Overloading working memory, either due to the large amount of information or through ineffective teaching and testing methods, complicates the retention of information. We will discuss methods for reducing working memory overload.

Good understanding and memorizing of mathematics teaching materials can be achieved through well-designed multimedia educational content. We will outline the fundamental principles of designing multimedia educational e-content. Effective implementation requires a thorough understanding of mathematics teaching by the instructor to create high-quality multimedia content for mathematics and present it in adequate way, aimed at enhancing understanding and memory retention of mathematical concepts through online teaching. Creating educational multimedia content for mathematics instruction necessitates utilizing appropriate principles, techniques, and tools.

2. COGNITIVE LEARNING THEORIES

Cognitive psychology considers the learning process internal, suggesting that the quantity of learned material depends on cognitive processing abilities, effort invested in learning, depth of processing, and prior knowledge. Focusing on the study of learning processes, cognitive psychology includes the examination of internal processes such as memory, motivation, thinking, and reasoning.

Cognitive theories, unlike behavioral ones, are grounded in mental processes (e.g., perception, recognition, understanding, memory, problem-solving, etc.). The origins of cognitivism can be traced to Tolman, who, through experiments with various animals, found that a hungry animal seeking food in a maze gradually makes fewer errors, forming a cognitive map of where the food is located. Through these experiments, Edward Tolman (1932) demonstrated that research on internal mental processes, alongside the behavioral approach, must be included in studies for more effective learning (Širanović, 2012).

Cognitive learning theories offer a productive mechanism for knowledge acquisition, requiring a certain level of intelligence for long-term application in various situations. Through introspection, or observing one's own mental processes, new knowledge is acquired. Thus, we have insight learning and hidden learning.

In insight learning, we have a connection between the situation we find ourselves in, the means, and the goal. When faced with a particular situation, reasoning leads to a solution. This method is more pronounced in intelligent individuals who can gain insight and find unique solutions. However, insight can be trained by observing various situations, asking new questions, and encouraging critical thinking.

In implicit learning, knowledge is used only when needed, forming a cognitive map in the mind. An example of this is the hungry animal in the maze. A similar example is when arriving in a new city, men typically look at a city map, while women notice observable details like shops and markets.

Connecting these learning approaches with mathematics instruction, there are problems that we sketch, and by observing the sketches, we determine how to reach the solution. Some students use different approaches when solving problems, demonstrating insight learning. By working on multiple problems, students can recognize similar problems and know the path to the solution, thereby training this type of learning. Mathematics problems can also require implicit learning, where students observe given data, create a cognitive map, and identify necessary formulas to find the solution.

There are two approaches to designing multimedia educational e-content: technology-focused and learner-focused (Mateljan et al., 2009).

The technology-focused approach emphasizes technological functionality for successful multimedia delivery. This approach focuses on achieving effective transmission of multimedia content, aiming to use technology efficiently. The learner-focused approach starts with the recipient's cognitive abilities, aiming to aid understanding and retention. This approach designs and tailors multimedia content to facilitate better and faster retention (Mayer, 2001).

Designing instructional content in online mathematics education is crucial for acquiring mathematical concepts. Capturing and maintaining the attention of both elementary and secondary school students is a significant challenge, even in traditional classroom settings. In addition to video discussions between the teacher and students, it is necessary to provide materials for learning and reviewing new lessons. To capture students' attention, materials should include multimedia content such as video clips, animations, and graphics. This helps retain lessons in memory longer, as multimedia elements remind students of the topics covered, allowing them to connect and apply memorized content.

2.1. **Cognitive Load Theory**

Cognitive Load Theory (CLT) is a cognitive learning theory introduced by John Sweller, an Australian educational psychologist, in the mid-1980s. The key premise of this theory is the focus on human cognitive architecture: the characteristics and interactions between long-term memory and working memory, and how cognitive load affects learning. Working memory is a critical component of this system as it allows new information to be integrated into long-term memory.

John Sweller's Cognitive Load Theory addresses techniques for reducing the load on working memory to facilitate changes in long-term memory related to schema acquisition (Schwartz et al., 2013).

One important aspect of John Sweller's Cognitive Load Theory is that heavy cognitive load can have negative effects on task completion. Experience with cognitive load shows varying effects. For example, older adults, students, and children experience different and often higher levels of cognitive load ("John Sweller's Cognitive Load Theory," 2018).

Cognitive Load Theory is based on the relationship between our working memory and long-term memory and explains how the learning process changes depending on cognitive load. Sweller argued that instructional design can be used to reduce students' cognitive load. Much later, other researchers developed methods for measuring perceived mental effort, which indicates cognitive load.

2.1.1. *Working memory*

In the past two decades, extensive research has been conducted on how people actually learn with respect to cognitive capacity, i.e., specificially through Cognitive Load Theory, which posits that information processing and knowledge construction are limited by the capacity of working memory. According to this theory, only a portion of the information will be processed and retained in working memory, while the rest will lead to overload, impeding information retention. Working memory is the part of the brain where information is temporarily held, worked on, and organized to achieve understanding (Sweller & Chandler, 1991).

We use working memory when performing new tasks, drawing on numerous pieces of information to successfully complete it. As previously emphasized, the amount of information that can be stored and duration it can be held in working memory are both limited. Working memory is crucial for integrating new information into long-term memory. The goal is to transfer information from working memory to long-term memory as quickly as possible and to free up space for the acquisition new information in working memory.

In order for information to be stored in long-term memory, it is organized in a specific way, allowing for vast amounts of information to be stored effectively. Once we have adopted these cognitive schemas, we can more easily access them in working memory. Therefore, our ability to manipulate vast amounts of information, which is necessary for task execution, depends on our familiarity with the task to be performed.

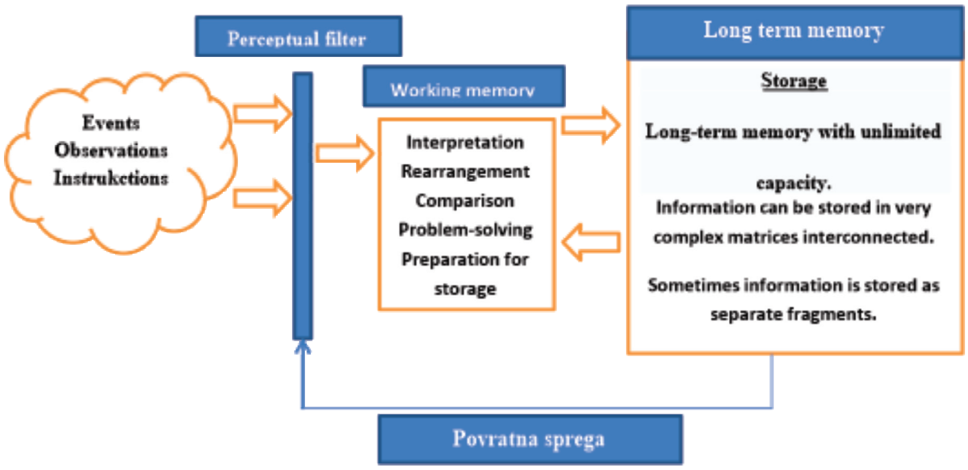

Figure 1: *Information Processing Model*

The Information Processing Model in Figure 1 shows that new information must first be perceived, then processed in working memory, and assimilated into long-term memory. If the schema is not fully adopted, it is necessary to keep all key information for task completion in working memory, which leads to greater conscious effort in performing the task. For the learning process to be effective, it is important that the amount of cognitive load does not exceed the capacity of working memory (Đuras, 2020).

We know that not all students have the same prior knowledge in a given area, so it is crucial to present new material in a meaningful way that builds upon previously learned content. However, preparing students in advance for the new lesson is also important. There are several ways to facilitate learning.

Since every lesson should include an introductory part aimed at activating students' prior knowledge of the chosen topic, this can be achieved by asking questions related to the new lesson's content, with the possibility of presenting a brainstorming session (one of the teaching methods), or solving a specific example on the board where previously learned material will be applied. If the lesson involves a new area, this part should define the basic concepts to be used and provide explanations before they are employed in the instructional unit, so that students are not confused when these terms are mentioned during the lesson. Using these methods helps students feel more confident with new material, participate more actively in the lesson, and engage more comfortably in providing answers and completing tasks.

Regardless of the amount of instructional content planned for the lesson, this method of preparation for the main part of the lesson provides a foundation for interactive learning, trains the students' minds, benefiting both those with weaker prior knowledge and those with stronger knowledge in mathematics. It shifts their attention to the new instructional unit while connecting it with previous material.

In mathematics, an important part of the lesson also includes the concluding section, in which the instructor highlights the most important concepts. These main points from the lesson need to be processed by students in working memory after being learned, so they can be stored in long-term memory. This creates a prerequisite for solving tasks from that area and for completing homework assignments.

Therefore, it is crucial to invest effort in every part of the lesson to ensure it is productive and successful, enabling instructors to meet the lesson's objectives and students to achieve the outcomes set for that instructional unit.

2.2. **Cognitive Theory of Multimedia Learning**

The Cognitive Theory of Multimedia Learning is one of the cognitive learning theories introduced by American psychology professor Richard Mayer in the 1990s. This theory is based on John Sweller's Cognitive Load Theory and is specifically applied to multimedia learning, thus sharing many similarities with it. Mayer's theory posits that human working memory has two subsystems (visual and verbal/auditory) that operate in parallel, and that learning can be more effective if both data processing channels are used simultaneously.

Mayer's theory is based on three assumptions suggested by cognitive research:
The assumption of dual channels - Verbal and visual channels (similar to what Baddeley referred to as the phonological loop and the visuospatial sketchpad) in our working memory are separate and can be used to process information simultaneously, thereby enhancing the learning process. The working memory model with multiple subcomponents was first introduced by Alan Baddeley and Graham Hitch in 1974 and revised

by Baddeley in 1992. These findings were later incorporated into Allan Paivio's Dual Coding Theory and subsequently into the work of Mayer and his colleagues.

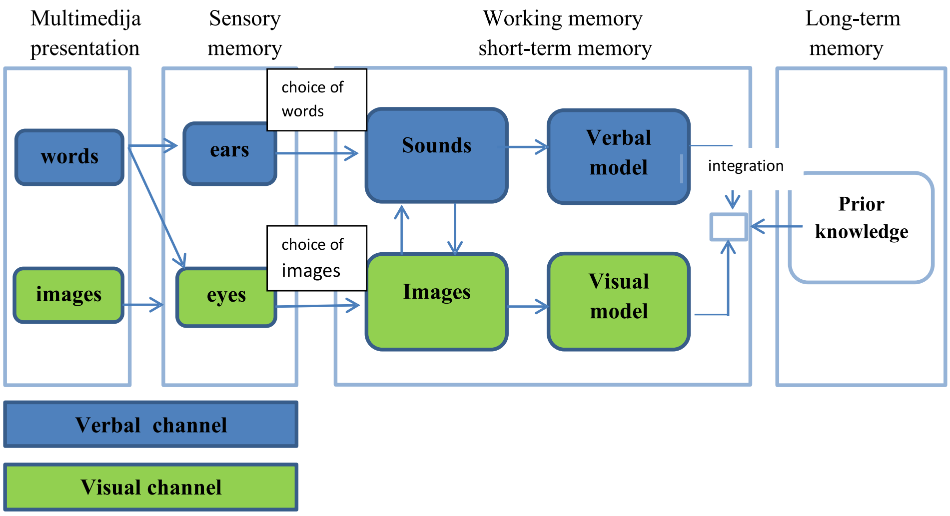

Figure 2: *Cognitive theory of multimedia learning*

1. **The assumption of limited capacity** - As Miller's information processing theory has shown, these channels have limited capacity and duration for holding information. Therefore, too much information can lead to cognitive overload.
2. **The assumption of active processing** - Learning is an active process of collecting, organizing, and integrating new information. This definition shows a similarity with constructivist learning (constructivist learning). (Mayer, 2001).

Online mathematics instruction provides us with a great opportunity to use multimedia content when presenting lessons. The platform should be designed to include not only mandatory video calls but also presentations with texts, images, animations, and video clips. Previous research indicates that combining multiple multimedia elements in order to transfer material from short-term memory to long-term memory.

For example, a trigonometry lesson can be presented more effectively through multimedia instruction compared to traditional classroom teaching. Along with the derived formulas, incorporating an image or animation from GeoGebra to show how the formula is obtained can capture students' attention. Drawing graphs of trigonometric functions will be more engaging through multimedia content. Additionally, demonstrating the practical applications of the subject area helps students understand why they are learning a particular lesson, how broadly it is applied in other fields, and in everyday life. When students see photographs and video clips of trigonometry's applications in architecture, astronomy, meteorology, economics, electronics, music, medicine, and other fields, they will get answers to the frequently asked question, “Why do we need sin(x), cos(x), tan(x), and cot(x)?”

The curriculum in our schools, including textbooks, is based on formulating lessons and creating tasks that do not integrate mathematical content with other areas, preventing students from understanding the purpose of learning the lesson. Online instruction offers greater access to resources, making it easier to present multimedia content and applications of the material during lessons. The reason for this is that students can independently access certain resources during class, whereas in traditional classroom teaching, they only have access to what the instructor has prepared in advance.

The PISA testing conducted in our country has shown very poor results (Džumhur, 2020) because our students learn certain topics but are unable to apply them, causing the instructional content to be erased from their memory. Therefore, we emphasize the importance of students learning the practical application of each subject area, and that lessons should be presented using multimedia content that will remain in their long-term memory. This way, the application will help them recall the material they have covered. By encountering these applications daily, students will associate them with the content they have learned. Online instruction offers a greater possibility for this compared to classroom teaching, as everything is readily accessible with a single click. It is evident that the most crucial factor is the design and creation of the lesson by the instructor.

The application of modern information and communication technologies (ICT) has become inevitable in all areas of life, including the learning process. In 2006, the European Parliament issued a Recommendation on Key Competences for Lifelong Learning, which includes eight key competencies, including digital competence. The National Curriculum Framework for Preschool Education and General Compulsory and Secondary Education of the Republic of Croatia has provided for the systematic treatment of the cross-curricular theme of the Use of Information and Communication Technology through the content of all subjects. As the most advanced available teaching tool and aid, ICT contributes to the development of students' abilities for independent learning and collaboration with others, as well as their communication skills, the development of a positive attitude towards learning, improvement in how students present their work, and enhancement of their approaches to problem-solving and exploration.

The use of ICT to enhance the quality of learning is commonly referred to as e-learning by most authors (Ćukušić and Jadrić, 2012).

Given that online teaching is a new development in Bosnia and Herzegovina with the arrival of Covid-19, both for teachers and students, all participants view it as a burden, not recognizing its endless positive aspects. Looking at it from a different perspective, alongside the improvement of digital literacy and learning various programs, online mathematics instruction can be more beneficial and effective in delivering content. Teachers may require more time to plan and execute lessons, but multimedia content can simplify everything, from drawing graphs to explaining lessons and performing formulas. Many online training programs on the digitalization of teaching are available, where teachers can enhance their skills. Successfully created content can be utilized in subsequent years. We will outline principles and effects that connect cognitive theories and facilitate the creation of effective online mathematics lessons.

3. PRINCIPLES AND EFFECTS OF CONNECTING COGNITIVE LOAD THEORY AND COGNITIVE THEORY OF MULTIMEDIA LEARNING THROUGH ONLINE INSTRUCTION

By integrating cognitive load theory and cognitive theory of multimedia learning through online teaching, and utilizing the principles and effects outlined below, we develop a more functional approach to presenting mathematics instruction via multimedia content. The goal is to reduce cognitive load and enhance the processing and retention of newly acquired information. **In addition to outlining the principles and effects, we provide explanations and applications within the context of mathematics instruction**.

3.1. Description of the principles

These principles facilitate the creation of higher-quality multimedia content in mathematics instruction. Below, we list and present them within the framework of mathematics.

- Modality Principle: Learning will be enhanced if textual information is presented in an auditory format, rather than solely in a visual format, when accompanied by other visual information such as charts, diagrams, or animations.
  - If students only watch a presentation, it can lead to monotony, causing them to lose interest in acquiring the information. The importance of classroom teaching lies in the interaction between the instructor and the students. This can also be achieved in online teaching by using a variety of multimedia content in the presentation along with video conversations between students and the instructor.
- The Modality Principle suggests that multimedia messages are more effective when students encounter spoken words and graphics. When instructors include text on the screen, they risk occupying the students' visual channel with both images and words, where students might inadvertently direct their cognitive processes to comparing the spoken and written text.
  - For example, defining trigonometric functions on the trigonometric circle and the signs of trigonometric functions can be more effectively presented through animation along with additional explanations from the professor that accompany the animation. This way, the student learns the material more quickly than by just reading text alongside charts, animations, etc. The focus remains on the animation, allowing the student to avoid spending time reading text next to it.
- Redundancy Principle**:** The capacity of both human information channels can be overloaded by redundant information, which negatively affects the learning process.
  - This principle applies when the on-screen text and the audio narration of graphics are the same. Adding text on the screen to a narrated image can lead to cognitive overload for students, as they are processing more information simultaneously. The material presented in online mathematics instruction should be concrete and avoid lengthy explanations of concepts, as this negatively affects student interest and can make the lesson monotonous and unengaging, which is not the goal. Therefore, it is

crucial to carefully design the lesson and find a presentation method that helps students remember the instructional content more effectively. The focus is on applying theory to practical problem-solving. Mathematics instruction requires student engagement and active participation, so it is very important not to overload students with unnecessary information. When students experience working memory overload, they may have difficulty learning and understanding mathematical content.

- Split-Attention Principle: When each source of information is crucial for understanding the presented topic, learning is enhanced when multiple sources of information are presented both spatially and temporally integrated, rather than in separate formats.
  - This principle indicates that in designing a lesson, including multimedia instruction, it is important to avoid materials that require students to divide their attention between multiple sources of information. Materials should be designed so that different sources of information are physically and temporally integrated, thereby eliminating the need for students to engage in mental integration. Removing the need for mental integration of multiple sources of information reduces cognitive load. When discussing a specific part of a mathematics lesson, it is preferable to simultaneously demonstrate solving a problem with narration, present a formula, or explain an animation with the instructor's voice, so that the lesson is structured to complete the instructional unit within the planned class time.
- Spatial Contiguity Principle: Processing information is easier when two related visual sources of information are closer to each other, for example, text placed near the relevant part of a diagram results in more effective learning than if the text is placed below the diagram.
  - This principle suggests that instructors should place text (such as labels or captions) close to the graphics they describe. By doing so, they minimize the cognitive effort students must expend to align the meaning of the text with the graphics themselves. Therefore, instead of wasting time scanning the screen to find connections between the presented content, students can devote all their cognitive effort to integration and building connections. Additionally, it is beneficial for students to read the text before the animated graphics so they know where to direct their attention. It is also useful to have the animated graphics displayed in parallel with the instructor's audio explanation.
- Temporal Contiguity Principle: Simultaneous presentation of information should align with the way the human mind functions, connecting what is logically related during the presentation. This yields good experimental results, as does presenting related multimedia information with very short time intervals between them.
  - Students learn better when relevant words and images are presented simultaneously rather than sequentially. This principle dictates that narration and animation should be delivered at the same time. A good example of this is when the instructor solves a problem and simultaneously explains the steps through speech. Similarly, when presenting a specific formula, it would be more useful to immediately show the graph from which the final formula is derived. If we want to highlight the application of certain material, it is desirable to include a video or images that demonstrate the words along with the narration.

- Coherence Principle (also known as the Seductive Details Principle): States that extraneous material, although it may be interesting, is irrelevant and consumes learning resources.
  - The material we wish to convey to students through online mathematics instruction should not contain irrelevant information that will distract students' attention unnecessarily. Before presentation, the content should be carefully aligned. Since learning is an active process, all details can interfere with students' construction of mental models to represent the material. To adequately address this principle, it is necessary to use graphics, brief text (such as formulas), and the instructor's speech that support learning objectives (avoiding extraneous text, decorative images, and background music).
- Personalization Principle suggests that students learn better from multimedia presentations when the words are presented in a conversational style rather than a formal one.
  - According to the Personalization Principle, using a relaxed tone in online classes can positively impact students. Instructors should avoid rigid, academic language and instead use more approachable words to explain mathematical concepts. Informal language has the effect of activating a social response in students, such as engagement in trying to understand what the instructor has said. As a result, students will pay closer attention to the lesson and problem-solving process, which is essential for them to solve problems independently. During instruction, it is advisable to use first and second person pronouns (”I”, ”we”, ”you”, ”our”, etc.), as well as polite language (”please”, ”could you”, ”let's”, etc.).
- Voice Principle: Indicates that students learn better when narration is spoken by a human voice rather than a machine-generated one. (Mayer, 2001)
  - The importance of this principle has increased with advancements in technology. It suggests that it is better for the instructor to use spoken narration rather than recorded sound, as this helps maintain students' attention more effectively. The lesson presentation can be interrupted with a question from the instructor to check students' engagement. In online mathematics instruction, this principle is crucial for understanding instructional units, particularly during task demonstrations and when assisting students with independent problem-solving. Additionally, when displaying graphics, animations, and background sound, it is advisable to omit the use of a video of the instructor to avoid distracting from the content. Multimedia content can enhance learning outcomes when used effectively.

The presentation framework is the area within which educational e-content is displayed. This framework can encompass the entire screen or the window of an application where multimedia elements and objects such as text, graphics, images, animations, etc., are arranged. It can be argued that the multimedia principle is the starting point for all other principles, as students are more engaged when exposed to both words and images, rather than just words. Effective use of images and words simultaneously encourages generative processing. Including images should complement the explanation of mathematical content. Images, graphs, and animations enhance the meaning of spoken words, i.e., provide additional clarification of concepts. In mathematics, animations are preferred over static images.

The problem of misunderstanding mathematics through online instruction can be reduced by applying the mentioned principles. Instead of presenting students with just ”dry text and numbers” on the platform, materials can be enriched with various colored charts and accompanying explanations which will arouse their curiosity. Certain topics can be demonstrated using animations, such as showing volumes of solids by pouring a liquid from one bowl to another to illustrate the relationship between the volumes of two bodies. The surfaces of figures, presented alongside formulas and standard problems, can be shown practically, for example, how a specific area is tiled, including its dimensions, etc. In this way, students learn the practical application of mathematical content, allowing the material to be stored in long-term memory by connecting it to its application.

3.2. **Effects**

Effects indicate how certain ways of creating multimedia content in mathematics instruction can influence student attention. They serve as guidelines for active student participation in online mathematics classes. Below, we provide effects and examples of their application in mathematics.

- Signaling Effect: Refers to the enhancement of learning outcomes by directing attention to relevant information. Signals are based on natural attention grabbers such as motion. In multimedia, this can be achieved through underlining, arrows, or color coding.
  - During the presentation of new mathematical content, students are faced with a plethora of information that can sometimes be difficult to connect. What will help them focus on the most important parts is the use of signaling. Signaling in mathematics can be achieved by underlining key concepts, framing formulas, connecting graphs and task steps with arrows, highlighting each part of a task with explanations, etc. This way, students will know what to pay attention to and how to integrate information to build their own mental models. However, moderation is key. Too much signaling can be confusing for students.
- Segmentation Effect: Learning could be more effective if continuous animation or narration is broken down into smaller segments.
  - Students learn better when multimedia messages are presented in segments or ”microparts” that are tailored to the specific lesson and student age group, rather than as a continuous whole. Once they grasp a smaller part, they can more easily focus on a new segment by connecting it to what they have already learned. Additionally, it is easier for instructors to review a specific part due to misunderstandings rather than the entire content. There are two ways to implement the segmentation effect. The first is to insert pauses between segments, which gives students time to perform necessary cognitive processes. The second way is to divide animations into meaningful segments, which provides students with learning support and makes it easier for them to master the material by displaying animations in partitions with specific time frames. This approach helps students understand the procedures shown in the animation. The segmentation process has a positive effect on memory and application of the material.

- Effect of Worked Examples: Reduces cognitive load by providing detailed demonstrations of how to solve a task or problem.
  - It is well known that demonstration is a crucial method in mathematics when solving tasks. The instructor's presentation of examples shows how to use formulas. Sometimes students find theory or formula derivation unclear because the material in mathematics is interconnected. Therefore, if students have not previously mastered or do not remember some part of the material used in a new mathematical unit, they can more easily recall it through examples. The demonstration method is the best for mastering lessons in mathematics, both in classroom instruction and in online teaching. The instructor can use a smart board or tablets, which make it much easier to write, erase, add signaling marks, and change colors compared to a traditional teaching. Additionally, if a student does not understand a part of the lesson and asks at the end of the class, the instructor can go back to the previous screen where the task was done, whereas in a classroom setting, the example would need to be redone.
- Reverse Effect: Teaching techniques that are highly effective with weaker students can have the opposite effect, meaning negative consequences, when used with stronger students. For these students, explaining only the steps or providing hints during task completion has a more positive impact on conceptual understanding.
  - This effect refers to the reversal of the effectiveness of teaching techniques for students with different levels of prior knowledge. The primary recommendation arising from the reverse effect is that instructional design methods must be adapted to the students' knowledge acquisition in a given area. The goal of learning is to construct integrated mental representations of relevant information, which requires significant working memory resources. To solve a task without overloading working memory, some form of guidance or direction is necessary. Teaching techniques that help students create schemas in long-term memory are more useful for beginners or students with low levels of prior knowledge. Conversely, for students with higher levels of knowledge, or those with more prior knowledge of the material, the opposite is true. Thus, the same instructions for solving a task may not have the same effect on all students. One reason is that they may already have their own schemas for solving tasks, so instructions from the instructor might confuse them. It would be beneficial to use a variety of methods and approaches based on students' prior knowledge. Students with low levels of knowledge lack schema-based understanding in the targeted domain and therefore need instructions to support them in reducing cognitive load when tackling new tasks. Otherwise, their working memory will be overloaded. In contrast, students with higher levels of knowledge enter task-solving with pre-existing schemas. Providing them with additional instructions may result in processing redundant information, thereby increasing cognitive load. They need to integrate components from long-term memory with the additional instructions. Such integration processes burden working memory. In this case, giving additional instructions becomes unnecessary.
- Effect of Collective Working Memory: When the complexity of the material being learned is low, individual learning is more effective than collaborative learning. For

complex materials, collaborative learning is more successful as it allows for the distribution of working memory load among participants (Schneider et al., 2018).

- Group work in mathematics has proven to be effective for solving tasks. Participants can divide the tasks among themselves and each work on solving their own example, then present their task to the group. All group members explain the process they used. This way, working memory facilitates more productive processing and easier understanding of the tasks. This principle is useful for more complex materials and tasks. However, for simpler tasks, individual learning is preferred, as it is essential for everyone to master the basics of a particular area. This has been experimentally confirmed as well as observed in practice. In online mathematics instruction, dividing students into separate virtual ”rooms” and then bringing them back to a common video chat to demonstrate their solutions could be implemented. The groups should consist of students with varying levels of mathematical knowledge.

Regarding the effects and their impact through online instruction, we can conclude that it is important to present the material to students in an engaging manner. For example, definitions and theorems should be written in red letters, important terms should be underlined, and so on. Utilizing animations, charts, and incorporating all elements that can capture students' attention and help retain the material in long-term memory is essential. What is presented through animations and videos should be shown in segments with specific pauses between each segment to facilitate easier processing of the acquired information.

In mathematics, the application of the demonstration method is crucial. This involves solving tasks with step-by-step instructions and detailed explanations to help students better grasp a particular lesson. In subsequent examples, it is beneficial to provide only verbal instructions to encourage students to engage in the work. The best way to assess the outcomes of a lesson is through students’ independent problem-solving. During this process, they utilize everything retained in their memory from the instructor’s presentation. Different methods should be used for students with varying levels of prior mathematical knowledge. When introducing new material and tasks from a new area, group work also enhances learning. Students should be divided into groups, each receiving specific tasks, with each group member responsible for a particular part of the assignment. This approach ensures that all students actively participate in mastering the material, assisting each other in reaching solutions. It encourages them to explore on their own and simplify the material, which they then present to the other students. This method yields good results both in traditional classrooms and in online instruction.

4. Conclusion

Creating high-quality educational multimedia content for mathematics instruction requires disciplined, educated teachers, instructors, and professors who invest time in the creative preparation of lessons. It is essential for the teacher to be familiar with the principles and effects of multimedia content design, grounded in cognitive psychology, to ensure the content is both high-quality and effective. The goal of well-structured multimedia mathematical content is to help recipients understand, comprehend, and remember a particular area as effectively as possible. This can be achieved by applying principles that guide us in creating as good as possible materials for mathematics instruction in primary and secondary schools. Therefore, the use of these principles and effects greatly facilitates the creation of online mathematics content.

A significant impact is achieved by connecting mathematics instruction with other areas and everyday life, which helps students process the lesson more easily in working memory and transfer it to long-term memory. Memorization causes cognitive overload for students, making it difficult for them to meet the demands placed on them. The main task of teachers and instructors is to simplify the material for online instruction, break it into micro-parts for easier student assimilation, and meaningfully present the content with the help of the mentioned effects and examples within the lesson, to facilitate the construction of new knowledge in mathematics. This approach will increase students' interest and make them more engaged participants in the learning process.

We have observed that working memory is quite overloaded, which slows down the acquisition, processing, and retention of material. Therefore, it is essential to enhance its function by incorporating lectures in the introductory part of the lesson, where the teacher introduces students to the topic to be covered, boosts their confidence, and improves their concentration. Whether through quizzes where students compete with each other in answering questions, providing examples, or defining new concepts, the introductory part of the lesson plays a key role in motivating students. The purpose of this section is to increase individual student participation in the class, strengthen confidence, facilitate interactive learning, and improve success. This has a very positive effect as it enhances understanding of a specific mathematics lesson, which motivates students to explore further.

A multimedia introductory part of the lesson improves conceptual understanding of fundamental concepts, especially the more abstract ones that require visualization. By using high-quality online materials, students approach learning more seriously with a higher level of interest, as they feel more prepared for the task, which helps them master the material in a shorter period of time. Information must be presented clearly with all necessary explanations so that students can see the purpose of learning the specific lesson.

Applying the principles and effects of creating multimedia content in mathematics lessons, we found that students were more engaged, actively participated in the class, and responded positively to the assigned tasks. All students completed their homework, presented it in the next class, and collaboratively created posters where they visually demonstrated the application of a specific instructional unit. When creating multimedia mathematical content, it is important to apply each principle judiciously. Excessive reliance on any single principle can lead to student disengagement.

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