The Effectiveness of Digital Education Based on the Use of Infographic Technology and Its Impact on Developing Visual Thinking Skills and Mathematical Achievement among Middle School Students

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***Abstract*—The current research aimed to identify the effectiveness of digital education based on the use of infographic technology and its impact on developing visual thinking skills and mathematical achievement among middle school students. The researchers employed a quasi-experimental method comprising a pre- and post-design with both experimental and control groups. The study was implemented in the academic year 1445 AH with a simple purposive sample of 64 students from the second intermediate grade in Dammam. The sample was divided into two groups: a traditional method group comprising 31 students, and an experimental method group using digital education based on infographic technology comprising 33 students. The main results were as follows: 1) Statistically significant differences were found between the experimental and control groups in the post-application of the visual thinking skills test and the achievement development test in favour of the experimental group. 2) A strong relationship was observed between achievement development and visual thinking skills using digital education based on infographic technology. Accordingly, the researchers presented several recommendations and suggestions for future practice and research.**

***Keywords*—digital education, infographic technology, visual thinking, mathematical achievement**

I. Introduction

Information and communication technology is one of the requirements of learning in the twenty-first century. Hence, it has been the responsibility of the educational sector to employ digital technologies in order to keep pace with the developments of the current era. Dealing with these developments has become inevitable as they bring new horizons that have contributed to preparing innovative generations to face the global challenges that have arisen in the education system. This has been reflected in mathematics and life applications which have been highly efficient in addressing such challenges due to the information and skills they provide to develop thinking in its various forms.

Electronic means have contributed to the development of the educational process, as the use of the Internet has engendered a change in the teaching methods and approaches adopted, such as the use of interactive presentation techniques and modern teaching methods [1].

Digital education is a form of education that involves tools, methods, and systems with a technological template. Through the use of one or more of these tools in the educational practices taking place between the teacher and learner, the interaction process is either conducted remotely using direct face-to-face communication through technological programs and systems, or the times may differ and the learner can receive learning any time they want [2].

Educational resources include digital images, videos, animated and non-animated models, interactive models, maps and audio recordings, training symbols and materials, drawings, and text documents, all of which are necessary to organise the educational process for students [3].

Hamed and Faeq [4] defined digital education as an education system that uses information technologies and computer networks to support and expand the scope of the educational process through a specific set of means, including computers, such as Internet and electronic programs prepared either by specialists in the ministry of education or companies.

Similarly, Al-Ghamdi [5] characterised digital education as an education that relies on digital technology in its various forms to create and provide educational content comprising activities and evaluation methods needed to achieve required educational and pedagogical goals.

The value that digital education adds by bringing smart networks and computers to the educational process includes both cognitive and educational aspects. It is, in its entirety, a true and practical translation of the philosophy of distance education, which is based on expanding the base of educational opportunities for students. It is not restricted by time, place, or a category of learners, nor is it limited to a specific type of education [6].

Digital education using technical media is a requirement for enhancing the use of technology in daily life. The Kingdom of Saudi Arabia, represented by the Ministry of Education, has implemented a policy to achieve its Vision 2030. Its aim is to keep pace with the use of technology in the educational process by introducing multiple reforms and major changes, starting with the implementation of e-learning systems and then disseminating the culture of digital education [7].

Shaltout [8] stated that infographic technology is a reflection of developments in the field of technology and its educational applications. Through its diverse designs, it

works to change the way in which complex data and information are read and displayed. It also adds a new visual form that presents an attractive image for the learner, and helps those in charge of the educational process to present curricula in new and stimulating ways.

These designs also provide different patterns with respect to displaying information, including those which are static, moving, and interactive, and each pattern differs in the design, type, and volume of information provided [9].

Today, most newspapers, blogs, and social media use a variety of visual data, collectively known as infographics. This type of display is viewed as a basic and independent branch that seeks to integrate technological innovations in an artistic and creative sense to present information in a concise, coherent, and interesting manner. It is thus considered one of the basic sciences that integrates technical and educational development [10].

Therefore, dealing with infographic technology at an educational and practical level through social media applications used in daily life has become an essential requirement for designing commercial advertisements and marketing in electronic newspapers. These now use presentations and illustrations that have contributed to promoting goods and products in record time. In addition, infographic technology has demonstrated its effectiveness in conveying ideas to the learner with ease and simplicity.

Among the studies recommending the use of infographic technology in all educational stages are those by [11], which confirmed the effect of employing learning based on the use of infographics to develop visual thinking skills among eighth-grade students learning history, and [12] which aimed to present the viewpoints and opinions of infographic designers creating infographics for educational purposes.

Saada [13] stated that employing infographics in teaching represents an attempt to enrich the educational process and make teaching and learning more effective so as to achieve teaching objectives and develop thinking skills.

In this context, mathematics is one of the fundamental subjects that develops learners' ability to acquire different patterns of thinking to solve mathematical problems, making it easier for learners to absorb new information. Learning is not limited to accruing mathematical knowledge to understand facts, knowledge and concepts, but rather includes linking such knowledge to the everyday reality of life by offering students an opportunity to solve daily problems in a way that enables them to practise all types of thinking in order to choose the optimal solution, this is what distinguishes mathematics in practical applications.

Salem [14] asserted that visual thinking represents one of the higher levels of thinking and, according to educators, plays a large and prominent role in creativity and innovation. The reason for this is that three-quarters of the knowledge a person acquires is visual, and the human brain can receive and process a large amount of visual information.

Conversely, Saeed [15] viewed visual thinking skills as one of the mental processes an individual practises through the meanings conveyed by the sense of sight, which enables them to obtain information contained in images, symbols, and drawings, including linear or colour expressions, with the assistance of other mental processes, and then express them verbally or visually according to each situation.

However, the importance of visual thinking is not limited to students as it is considered one of the necessary skills for all those working in the field of education. It plays a major role in facilitating the exploration of practical facts, achieving scientific understanding and communication, clarifying scientific ideas and sharing them with others, and enhancing the development of critical thinking and innovative thinking [16].

Therefore, the importance of visual thinking becomes clear when students are given a new opportunity to use different thinking styles, as it is an influential factor that encourages learners to participate and interact, which contributes to increasing their understanding and comprehension.

Several studies have emphasised the importance of developing visual thinking skills at different educational levels, such as a study by Jassim [17] which examined visual thinking skills in the fourth-grade primary mathematics book, and a study by Al-Attar [18] which explained the effectiveness of the generative learning model and thinking maps in developing visual thinking skills among middle school students.

On the other hand, there are several studies have focused on digital education using infographic technology and its impact on developing mathematical achievement in different specializations and stages, including [19], which aimed to investigate the impact of digital education using smart devices on students' academic achievement in the educational media course and their tendency towards using smart devices in teaching and learning. While Ibrahim [20] aimed to identify the effectiveness of using visual thinking networks in developing visual thinking skills and academic achievement in mathematics for those with learning difficulties. [5], the purpose of which was to investigate the effectiveness of educational infographics in academic achievement and developing geological sense.

Thus, it is apparent that digital education is one of the modern teaching models based on infographic technology that contributes to students acquiring visual skills through effective pedagogical methods supported by images and illustrations to make the education process fun and interesting. It is therefore essential to study the effectiveness of digital education based on the use of infographic technology and its impact on developing visual thinking skills and mathematical achievement among middle school students.

Based on the literature review above, and the results of initial survey which was conducted by the researchers with 11 teachers of middle stage mathematics at the Eastern Province. The results of the initial survey interviews showed that five teachers used the traditional teaching method, which is represented by the use of the pen and the board in the process of writing, explaining and solving exercises and the textbook, without the diversity in their teaching methods, and they also showed negative trends towards technology, because they think it requires prior training and takes longer to implement it. While six teachers showed positive trends towards the diversity of teaching methods and the use of technology, because they have previous experience and practice, which was reflected in the students' achievement level.

In addition, when the follow-up records of students were

reviewed, the researchers noticed that the average grades of students who were taught through the traditional method did not exceed a very good grade compared to female students who were taught through modern teaching methods (technology), as their average grades reached an excellent.

There is therefore a need to address this gap by investigating the effectiveness of changing from a traditional method of teaching to a more technical one, therefore, the current research problem was addressed by answering the main question:

What is the effectiveness of digital education based on the use of infographic technology and its impact on developing visual thinking skills and mathematical achievement among middle school students?

The sub-questions that branch out from this question were as follows:

1) What is the effectiveness of digital education based on the use of infographic technology and its impact on developing visual thinking skills among middle school students?
2) What is the effectiveness of digital education based on the use of infographic technology and its impact on developing mathematical achievement?
3) What is the correlation between developing visual thinking skills and mathematical achievement among middle school students?

To answer these questions, the researchers sought to achieve the following objectives:

1) Identifying the effectiveness of digital education based on infographic technology and its impact on developing visual thinking skills among middle school students.
2) Identifying the effectiveness of digital education based on infographic technology and its impact on developing mathematical achievement among middle school students.
3) Determining the correlation between developing visual thinking skills and mathematical achievement.

The theoretical and applied importance of the current research is detailed as follows:

Theoretical importance:

- This research is in line with modern trends in education that seek to ensure learners achieve mastery of visual thinking skills and mathematical success, as the role of digital education based on infographic technology has now been activated and it is used in learning and teaching mathematics.
- There are no studies – to the best of the researchers' knowledge – that have addressed digital education based on the use of infographic technology in teaching mathematics; hence, this study is a new addition that enriches Arab literature on the use of new technology in education.
- The importance of the research stems from the importance of digital education and using infographic technology as a modern educational tool.

Applied importance:

- Opening the way for other research to use digital technologies in teaching mathematics and other academic subjects.
- Helping students acquire visual thinking skills and mathematical achievement through the use of digital education based on infographic technology.
- Building advanced educational curricula that ensure the comprehensive development of students, enabling them to contribute to building their community to keep pace with rapid developments in digital education.

It is an important to explain for the reader the study terms as following:

A. Digital Education

Saeed [21] defined digital education as harnessing the use of technological means in education to facilitate students' individual and collective learning, and making them the focus of the lecture. It achieves this by starting with the technologies used for presentation and ending by going beyond the physical components of education, such as the smart school and virtual departments through which interaction takes place between members of the educational process via the Internet and interactive video technologies.

The researchers define it procedurally as an interactive education system available via the Internet that includes all parties involved in the educational process (teacher, student), one that is not limited by time and place, and enables learners to complete all the tasks and duties required of them and submit them digitally with ease and flexibility.

B. Infographics Technology

Infographics technology was defined by Issa [22] as a technical term that refers to converting complex information and data into graphic images that are easy for those who see them to understand without needing to read an abundance of text. Infographics are now considered one of the important and effective tools, and the most attractive for displaying information, especially through social networks, as they combine ease, speed, and entertainment in displaying information and communicating it to the recipient.

The researchers define it procedurally as employing technical and digital means to transform difficult abstractions (information, data, concepts) into expressive images and illustrative drawings in which the mind can absorb the diverse information with the aim of conveying educational ideas to the learner quickly and clearly.

C. Visual Thinking

Mohamed *et al*. [23] defined visual thinking as a mental process that depends on observation and viewing, which students perform when they are shown historical pictures, videos, or maps. This enables them to perceive the relationship between what they see from these pictures, interpret and analyse the information, and deduce and extract historical meanings from it.

The researchers define it procedurally as a group of mental processes that develop the learner's ability to distinguish similar information and simplify complex concepts in order to easily reach a solution to a specific issue or problem. In so doing, they are stimulated to think about employing the sense of sight to rewrite and formulate what the information contains (symbols, signs, images, geometric shapes) through interpretation analysis, inference, comprehension and understanding, convert it into spoken or written language, and store, memorise, and retrieve it when needed.

D. Mathematical Achievement

Al-Dayri [24] defines it as the sum of information and knowledge acquired by students through the unit (Geometry and Spatial Reasoning) from the Mathematics Book for the Second Intermediate Grade, using infographics, and is measured procedurally by the score they obtain in the test prepared for this purpose.

The researchers define it procedurally as the total score obtained by the student from (information, knowledge and skills) in the achievement test prepared by the researchers.

II. Theoretical Framework

This section presents the theoretical framework for the research, and it is divided into three parts: Digital education, infographics, and visual thinking.

Infographics can be an effective visual approach to passing on data and supporting conceptual understanding since individuals see with their brains [25, 26]. The more visual the input is, the more likely the visual will be recognized and reviewed, hence making vision an effective instrument for learning [27]. Numerous learning and message design theories support this idea. For example, Nelson's picture superiority theory describes how individuals learn concepts more effectively by seeing pictures than by perusing content alone since human brains are basically hard-wired for visuals the exceptionally engineering of the visual cortex gives coordinate get to human awareness [28].

Furthermore, according to Pavio's [29] dual coding theory, people encode information from images using both verbal and visual codes, activating several brain pathways to assist memory. From an educational standpoint, infographics help students focus, reduce cognitive load, produce visually appealing artifacts, activate or develop schema by utilizing familiar items and information, and motivate [30].

A. First Axis: Digital Education

The world is witnessing significant transformations in the area of education, along with a huge technological revolution via computers or the Internet, as digital education is a modern educational means that works to provide an appropriate educational environment for the learner.

1) Historical overview of digital education

The term digital education (e-learning) was first proposed by Jay in 1992 and became widely used in 1999. With the advancement and development of technological tools, the term has been interpreted in different ways, such as online training and distance learning. Synchronous and asynchronous network education is used to break through the constraints of time and place [31].

The concept of digital education elements has developed significantly since its inception. This is due to the development of educational environments through the increased use of the Internet and reliance on digital education, and modernisation of the structure of digital repositories and their development in line with the requirements of this era. Fig. 1 depicts the historical development of the concept of learning elements [19].

2) What is digital education

Definitions of the concept of digital education have varied and diversified according to the viewpoints of researchers, and include the following.

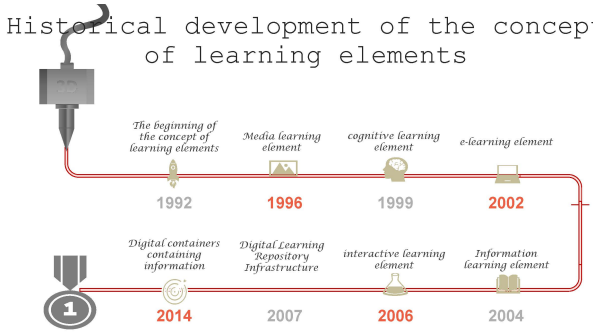


Fig. 1. The historical development of the concept of learning elements.

Shamsi [32] defined it as an innovative educational method that digitises tools and technologies in the educational process, uses modern interactive communication mechanisms for learners or trainees, and provides interactive educational programmes from various sources.

Ahmed [33] defined it as e-learning in its latest form, which relies on the latest developments in technology and its stages in its teaching methods, evaluation methods, and other techniques related to the educational process.

Al-Maliki [34] defined it as education that takes place through digital technological media, using the Internet, and is either direct or indirect, allowing the student or teacher to obtain knowledge at any time and from any place.

3) Digital education components

The components of digital education are multiple but can be grouped into three basic types [35]: 1) The educational component: this includes students—professors—educational materials—administrators—financial—library—laboratories—research centres—exams. 2) The technological component: this consists of a website—personal computers—network—converting the educational component (digital content). 3) The administrative component: this includes multiple goals—the philosophy—plans, programmes and budgets—timetables for digital education—strategy and goals for both the short and long term—preventive and therapeutic control of deviations from digital education programmes.

In light of this, the researchers believe that all components of digital education (educational, technological, administrative) work as part of an integrated system by complementing each other, and the success of the educational process is not complete unless they are available, which contributes to ensuring the progress of the educational process.

4) Types of digital education

Digital education has multiple types and these can be classified as follows [36]:

- Synchronous digital education: Electronic learning in which the teacher and the learner meet at the same time
- Asynchronous digital education: Consists of a connection between the teacher and the learner through which the teacher can place resources along with a teaching plan and evaluation on the educational website.

The student then enters the website at any time and follows the teacher's instructions to complete the learning without the need for synchronous communication with the teacher.

- Blended learning: Includes a group of media that are designed to complement each other, and can include multiple learning tools such as instant virtual collaborative learning software, self-learning courses, and learning systems management. Blended learning also combines multiple activity-based events that include learning in regular halls where the teacher meets with students face to face, and self-learning which is both synchronous and asynchronous.
- Distance education: A learning method in which the available means of communication and contact play a fundamental role in overcoming the problem of long distances separating the teacher and the learner, as this system generally means transferring learning to the learner at their place of residence or work instead of the learner attending the educational institution. On this basis, the learner can combine learning and work according to their needs, and adapt the curriculum and speed of progress in the subject matter in accordance with their special conditions and circumstances.

Therefore, it is clear that the multiple types of digital education available (synchronous education, asynchronous education, blended education, distance education) aim to deliver information to the learner in a multitude of different ways. This also contributes to saving time, effort, and costs for researchers who can access different types of information easily and ultimately leads to the effective presentation of educational content.

5) Advantages of digital education

Digital education has multiple advantages, as cited by both [37, 38]: Firstly, low cost, as it is possible to design and produce a single educational image suitable for different educational scenarios. Secondly, the learning element containing text, audio, and images may help attract students' attention and increase their motivation to learn. Thirdly, flexibility, as it is possible to modify the learning element to suit educational situations and the requirements of students. For instance, the same element can be used with a group of people with special needs by making simple modifications. Fourthly, the learner's chronological age is not an issue, as it is suitable for teaching adults, employees, and children whose circumstances do not allow them to be in schools and universities at specific times. Fifthly, it allows the learner to obtain more information as long as they exhibit acceptance and readiness, in contrast to what is available in regular education.

The researchers summarise the advantages of digital education in the following points (Fig. 2):

1) Displaying educational content supported by audio, video, and digital images help to strengthen observation, enhancing comprehension.
2) Provides flexibility in education and learning whilst giving users the opportunity to change and modify the content.
3) Digital education is less expensive and effortful compared to traditional education.
4) Gives complete freedom to the learner to choose the appropriate time and place to study.

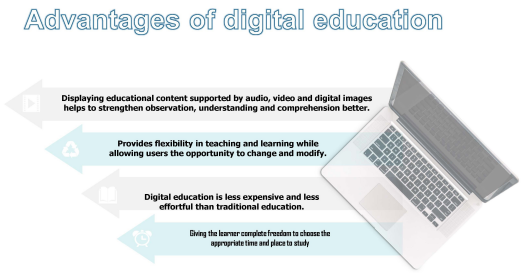


Fig. 2. Features of digital education.

6) Digital education objectives

Digital education aims to achieve the following set of objectives in the field of teaching and learning processes, as indicated by numerous scholars [31, 39, 40]: Firstly, meeting the needs and desires of learners in accordance with various cognitive and scientific aspects. Secondly, storing acquired information and accessing it at the appropriate time. Thirdly, quickly renewing information, knowledge, and ideas, and organise them according to their importance and realistic situations. Fourthly, developing and enhancing interaction between the educational teacher and students who are proficient in the educational process.

In light of this, the researchers believe that the main goal achieved by digital education is to encourage students to use technical and digital means in flexible educational methods that serve all parties to the educational process without conditions or restrictions, whilst giving students the opportunity to be responsible for searching for new sources of information at any time and place. This encourages learners to acquire the skill of self-learning and provides an interactive educational environment that benefits both the teacher and the student.

7) Obstacles to digital education

Unfortunately, the educational process faces a number of difficulties that may hinder application of the use of digital education, as mentioned by a number of scholars [36, 40, 41]. These are presented as follows: Firstly, the need to rely on specialists in the field of managing digital and electronic education systems. Secondly, the high financial cost of this type of education. Thirdly, the weakness of the skills of some learners and trainees in the effective use of various types of devices approved in the digital education process. Fourthly, the low level of response and lack of interest in this type of education among learners and trainees.

The researchers summarise these obstacles in the following points:

1) Lack of awareness or conviction among community members of the importance of this type of education.
2) The high economic cost in terms of designing and preparing training programmes and maintaining devices.
3) Large amount of time spent engaging with the electronic screen, both mentally and physically.
4) High educational loss.
5) Weak infrastructure of telecommunications companies to

serve digital education and its tools.

8) Studies that dealt with digital education

Al-Shahwani and Al-Naimi [42] presented in their study the reality of teachers' use of digital knowledge in teaching mathematics and natural sciences within the Majer and Hill series at the intermediate stage. The community represents (1436) teachers, and the sample represents (25%) of the community with (359) teachers. They used the descriptive approach, and the results showed the presence of statistically significant differences at the level (0.05) attributed to the variable of teachers' use and integration of digital education technologies in teaching. It also showed that there are statistically significant differences at the level (0.05) attributed to the variable of teachers' employment of digital teaching methods and strategies and teachers' implementation of the lesson in light of electronic digital knowledge. Redesigning the teacher's guide accompanying mathematics and science books to help teachers improve their performance in implementing digital teaching methods, and developing models for teaching plans in light of digital knowledge.

Al-Qarni [43] aimed to anticipate the future of digital education and learning after the Corona pandemic. To achieve the study objectives, the researcher used the descriptive predictive approach. The first study was an open questionnaire in which (30) experts participated. The second study was a closed questionnaire in which (25) experts participated, then the same tool was redistributed in which (15) experts participated. The study reached a list consisting of (94) indicators for the future of digital education and learning, represented in two main aspects. The first was related to the opportunities aspect and contained (79) terms distributed over 6 axes, and the second was related to the challenges aspect and contained (15) terms merged into one axis. The study recommended adopting the experts' forward-looking opinions that it reached and benefiting from them in rehabilitating, evaluating and developing e-learning systems and platforms.

In a study conducted by Ali [44] entitled A Future Vision for the Advancement of Educational Institutions in Light of the Requirements of Digital Education. To achieve the objectives of the study, the researcher used the descriptive experimental approach. The research sample consisted of two groups: the first group (19) faculty members, and the second group (90) middle school students. The results showed statistically significant differences between government schools, experimental schools, and private schools in terms of speed of performance, mastery, ease of understanding, information delivery, electronic communication, time management, self-learning, desire, attendance, and perseverance in favor of experimental schools

Kansara [45] addressed in his study the role of digital education in achieving educational reform from the point of view of educational supervisors using the Madrasati platform. To achieve the objectives of the study, the researcher used the descriptive analytical approach, and the questionnaire was used as the main tool for collecting data (and the study community consisted of educational supervisors using the Madrasati platform, numbering (507) working in the city of Makkah Al-Mukarramah, and the study sample consisted of (320) educational supervisors out of the total users of the Madrasati platform, representing (63%) of the original community. The researcher concluded that the study enjoys high stability and credibility. The study reached a number of results, the most important of which are: The degree of importance of applying digital education came to a high degree, which indicates the existence of a strong correlation between the reality of education and the use of the Madrasati platform.

Al-Ghamdi [5] presented in her study the necessary educational requirements related to the learner, family, and teaching staff, to achieve moral education in digital education. The descriptive analytical approach was used due to its suitability to achieve the objectives of the study. One of the most prominent features of the study was reaching a number of proposed requirements, the presence of which guarantees the achievement of moral education in digital education. The requirements were placed under three axes: requirements related to the learner, the family, and the teaching staff.

In another study conducted by Al-Harbi [46] aimed to study the degree of possession of the requirements for teaching mathematics in the digital age among secondary school mathematics teachers in light of some variables, the research used the descriptive analytical method, and the research sample amounted to (83) male and female teachers, who were selected by the intentional sample method, and the questionnaire for the requirements for teaching mathematics in the digital age was applied electronically. The research results showed: There were no statistically significant differences at the significance level ($\alpha \leq 0.05$) attributable to the gender difference variable (males, females) attributable to the difference in experience (long, medium, short).

9) Comment on studies that dealt with digital education

- Looking at the current study and comparing it with previous studies, we find that the current study was distinguished from previous studies in that it seeks to know the effectiveness of digital education based on infographic technology in developing visual thinking skills and mathematical achievement among middle school students.
- When looking at the approach followed in previous studies, we find that the current study was distinguished from the previous study in following the quasi-experimental approach, while previous studies followed the descriptive approach as a whole, such as the studies [42–44]. And the descriptive analytical approach, such as [5, 45, 46]. And the descriptive predictive approach, such as the study [43].
- It is also noted that the tools of previous studies are diverse due to the difference in their objectives, as these studies showed the effectiveness of digital education in students' mathematical achievement.

B. Second Axis: Infographic Technology

Infographics are one of the modern means that are rapidly spreading across social media sites. Their importance is not only evident in advertising, publicity, and marketing but also in the education sector, as they have become an attractive and exciting element in the educational process.

1) Infographic concept

The word 'Infographic' consists of two terms: Information, meaning information and facts, and Graphic, meaning pictures and drawings, thus it means pictorial information or visually represented information, which can also be called information designs [47].

Ricardo [48] defined infographics as a tool for visually summarising large amounts of information: it is simple when it explains information in a graphic form, and complex when it explains information in the form of a story comprising a series of pictures.

Krum [49] defined infographics as the largest graphic design that combines data displays, illustrations, texts, and pictures in a single format that tells a complete story.

Afashi [50] defined infographics as visual representations of information and ideas that combine visual data such as images, illustrations, and texts in a stimulating way that simplifies ideas and helps in understanding them clearly, and through which information can be disseminated and circulated.

2) Types of infographics

Many researchers [51–54] have agreed that infographics are divided into three types, each of which has a specific form and use, and these are as follows:

1) Static infographics: These are fixed promotional graphics and texts that are printed, distributed, or published on Internet pages to explain information and ideas about a specific topic chosen by the owner of the infographic in a fixed manner. They are divided into two forms:
   - Vertical static infographics: These constitute the vast majority on the web. They are also suitable for display on laptops, tablets, and smartphones. They are easy to interact with, making it easy for users to view them. A notable drawback is the lack of clarity of components in the lower area when using presentations or paper printing.
   - Horizontal static infographics: These are more suitable for reviewing historical events, as the clarity of their components is lower outside the special programs used to produce them. They are mostly used to present the development of a historical event.
2) Animated infographics: These are animated graphics with which the learner interacts to explain a specific piece of information. They are divided into two types:
   - Regular video recordings on which information and explanatory data are placed in an animated manner to display concepts and facts in the video. This type is rarely used.
   - Designing data, information, and explanations in a fully animated form. This type requires a substantial amount of creativity and choosing expressive movements that present the information in an interesting and enjoyable way. This is the most commonly used type.
3) Interactive infographics: A visual display of information and data such as images and drawings that allow more participation and interaction with the user who can control them by clicking on them; therefore, it is more expensive than static infographics.

It is clear from the above that each type has a specific form and use in teaching mathematics, as the first type is concerned with a static display of data and has the freedom to move vertically or horizontally, the second type is concerned with displaying data in an animated form, and the third type is concerned with user interaction according to its particular purpose, which contributes to simplifying information, attracting the attention of learners, and enhancing their interaction with the educational content.

3) Infographic design principles and standards

Pretlow [55] stated that there are a number of important principles for producing effective infographics, including the following:

1) Study the target audience to find out what really suits them.
2) Maintain the unity of the design: through initial planning, identify the main ideas and the most important information.
3) Consider the sequence as this gives importance to the content and directs the recipient to what they should see first.
4) Maintain simplicity and focus by monitoring the amount of information provided so that it is not excessive and serves the required purpose.
5) Appropriateness of the colour and font used. Use harmonious and eye-pleasing colours, and preferably one type of font.
6) Documenting references, where the source of the information used in the design must be mentioned.

Issa [22] also added some important tips for designing infographics: Firstly, choose one topic for each infographic. Secondly, choose information that can be represented visually. Thirdly, verify the accuracy of the information presented. Fourthly, choose a distinctive title for the infographic topic. Fifthly, integrate images and graphics, ensure simplicity in information, and avoid long sentences. Sixthly, mask the basic components by highlighting relationships and collecting similar items information and then linking them together. Seventhly, mention and attach a list of information sources.

Smiciklas [56] stated that the criteria for successful infographic design are as follows: visual persuasion, selection of graphics, geometric shapes, learning topic criteria.

We conclude from the above conditions for the success of infographic design that following the most important rules and principles in design leads to creativity and excellence in obtaining a high-quality design, which contributes to communicating ideas effectively with ease and simplicity.

4) The importance of infographics in teaching mathematics

The importance of infographics in teaching mathematics, as cited by a number of scholars [16, 52, 57], can be summarised in the following points:

- It may make teaching and learning mathematics more fun and exciting due to the effects of colours and the attractive, harmonious images it contains.
- It contributes to conveying the message and educational goal quickly due to the focus of information and its visual presentation.
- It may enhance learners' enjoyment of learning mathematics, encourage them to accept and engage in

various teaching activities, and make them feel joy and happiness due to the attractiveness, clarity, and simplicity of infographics, and the ease of understanding the content.

- Its rapid spread among learners due to the ease of sharing via social networks.
- Saving time and effort for both the learner and the teacher.
- Contributing to addressing individual differences.

In light of the above, the researchers summarise the importance of infographics in teaching mathematics as follows: First, infographics contribute to encouraging and motivating students and stimulating them to learn mathematics. Second, infographics enhance individual learning and collaborative learning among students. Third, infographics facilitate the learning process by presenting complex and abstract concepts and converting them into images and drawings that work to consolidate the information in the student's mind for a longer period. Fourth, learning using infographics technology breaks the daily learning routine, which contributes to developing the learner's visual thinking skills. Fifth, using visual elements in teaching mathematics is more practical in terms of saving time and effort and reducing the cost for the student and the teacher. Sixth, a diversity of teaching methods in the classroom environment plays a major role in directing the student's attention towards learning mathematics whilst taking into account individual differences.

5) Infographic Design Programs

Mansour *et al.* [58, 59] indicated that there are numerous tools and programs that allow teachers and learners to design infographics in different styles, the most prominent of which are:

- Adobe Illustrator: This is the premier program for designing infographics for designers, due to its extreme flexibility and ability to give attractive results.
- Adobe Photoshop: This program can be used to design infographics, although it will not be as flexible as Illustrator as it is a photo editing program, but it can be used to display data in a beautiful way.
- Inkscape: For those who prefer to use a free program, Inkscape is an alternative program to Illustrator.
- Tableau: This is a free program that works on Windows only and is used to create colourful and unique designs.
- Adobe Fireworks: This is a beautiful program for designing infographics, but it is limited in use despite being incredibly effective.

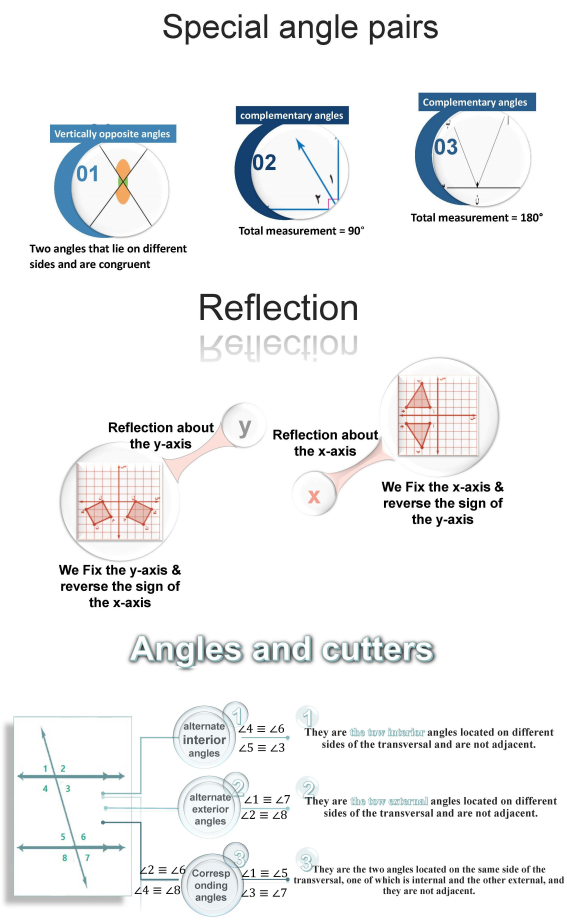
In addition to these programs, there are sites that enable users to design infographics and share these to create graphic statistics. There also exist other sites that help in designing infographics online and provide ready-made templates for beginners for free, including:

- Piktochart: This is a site specialising in designing and developing infographic designs and is useful for beginners. It also offers the drag-and-drop feature for shapes. A number of free templates are available for users to start designing their own infographics. Designs are available in high-quality PNG, SvG and JPG extensions.
- Easel.ly: A free tool for creating infographics from ready-made templates that supports Safari, Firefox, and Chrome internet browsers.
- Canva: A site specialising in creating infographics that features free drag-and-drop technology.
- HoHli: Creates charts in a simple way. All users need to do is to choose the appropriate model, add the data, then customise the colour and size as required.
- Creately: An important tool for creating pre-designed charts and graphs. All users have to do is add their data to complete what they have achieved and share it with others.

In this study, the main stages of designing digital education based on the use of infographic technology using the general ADDIE model as following:

1) Analysis: Through this stage, the researchers analyzed the characteristics of learners.
2) Design: In this stage the researchers determined general and procedural objectives and appropriate teaching strategies based on the objectives and learning outcomes in the form of measurable phrases.
3) Development: By identifying the programs used, which are PowerPoint + Napkin + Allppt + Canva + GeoGebra.
4) Implementation (application): In this stage, the available educational tools was applied inside the classroom so that the teacher directed students to learn, apply the activity, and provide feedback.
5) Evaluation: The effectiveness of teaching was measured by applying pre- and post-test tools, organizing and analyzing data, and extracting results from them.

Infographic Design Examples (Fig. 3)



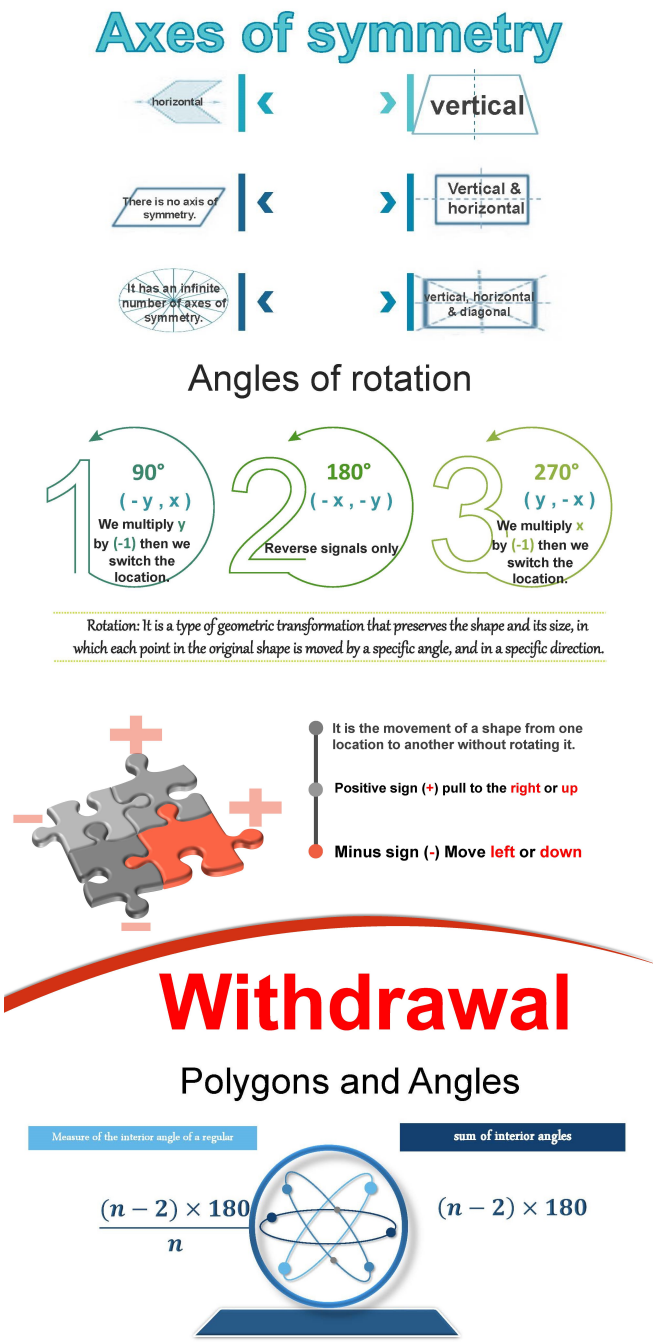


Fig. 3. Examples of infographic design (all drawings by researchers).

6) *Studies that dealt with infographics*

Noh *et al*. [60], which aimed to use infographics as a tool to facilitate learning, and the study sample consisted of (99) learners in the Faculty of Arts at Mara University of Technology, and the experimental method was used, and the study concluded that the difficult learning problems that learners faced were represented by the lack of appropriate guidelines for completing the required tasks, while others found that the frequent use of presentation slides and information provided by trainers was an obstacle to learning in classrooms, and the results of the study revealed the advantages associated with infographics such as: the use of images, symbols, good design and attractive colors can encourage learners to better understand the information, and studies investigated the effectiveness of infographics with female graduate students.

Sudakov *et al.* [61] presented a study that aimed to identify the aspects of using infographics in learning mathematics. The researchers followed the descriptive approach and the study sample consisted of (38) male and female university students in the United States of America. A questionnaire was also used to collect data on the importance of using infographics, their advantages and difficulties. The most prominent results of the study are positive attitudes towards infographics and their possession of information analysis skills and a high level of creative thinking.

Fayed *et al*. [62], focused on discussing the effect of using infographic technology in developing critical thinking skills in social studies among middle school students. The research sample consisted of (76) male and female students from the first year of middle school in Kafr El-Sheikh Governorate. The sample was divided into two groups: an experimental group (39) male and female students, and a control group (37) male and female students. The research revealed statistically significant differences at the level of (0.01) between the average scores of the students of the experimental and control groups, and the difference in favor of the experimental group in the pre- and post-application of the critical thinking test in the total score of the test.

Khalil *et al*. [63] conducted a study aimed at identifying the use of infographic technology in teaching science to develop systematic thinking among middle school students. To achieve the study's objectives, the quasi-experimental approach was used, with two groups (experimental and control), as it was applied to a sample of (60) first-year middle school students. The pre- and post-test was applied. After conducting the appropriate statistical analyses, the research reached the effectiveness of teaching the first unit of the science book (matter and its composition), which was formulated in light of infographic technology to develop systematic thinking among first-year middle school students.

Yousef *et al.* [64] addressed the effectiveness of using infographic technology in developing habits of mind and acquiring scientific concepts among primary school students in the State of Kuwait. The (Mind Habits Scale - Scientific Concepts Test) was applied to a random sample of (90) male and female students from the fifth grade of primary school. Among the most important results of the research is that there is a statistically significant difference at the significance level (α = 0.01) between the average scores of students in the experimental and control groups on the Mind Habits Scale (dimensions - total score) in favor of the experimental group. It also showed the presence of a positive correlation (0.78) statistically significant between the scores of the experimental group members on the Mind Habits Test and their scores on the Scientific Concepts Test after application.

l-Shammari *et al.* [65] aimed at the effectiveness of using infographics to teach mathematics in developing mathematical thinking skills among second-year middle school students. To achieve its goal, the researchers followed the experimental approach, as the research sample consisted of (50) second-year middle school students who were chosen using a simple random sample method. The experimental group numbered (25) students and studied using infographic presentations, while the control group numbered (25) and studied using the usual method. The research found that there

were statistically significant differences between the average scores of the experimental group and the control group in the entire mathematical thinking skills test in favor of the experimental group. The researcher recommended using infographic presentations in teaching mathematics because of their impact on developing mathematical thinking skills and holding training courses for mathematics teachers and training them on how to design and prepare infographic presentations.

7) Comment on studies that dealt with infographics

- The current study agreed in terms of the methodology followed, which is the quasi-experimental methodology, with previous studies that dealt with infographics, including the studies [60, 62–64], while that study differed from the study [56], in following the descriptive methodology.
- This study also agreed with previous studies in terms of the goal for which the study was conducted, which is to develop the skills of education, achievement and thinking among students at various educational levels (primary, middle, and university).
- It is also noted that the current study differs from previous studies that dealt with infographics in the tools used to achieve their goals, which is the questionnaire tool.

C. Visual thinking

Thinking is a daily, permanent, and continuous process a person uses in various aspects of their lives, whether this is in making decisions or solving daily problems. It has become a somewhat complex process and includes several processes and skills, starting from receiving stimuli, undergoing experiences and organising them, and then integrating them with the person's cognitive stock. This requires training and practice, which may be achieved through the student's experiences [66].

1) The concept of visual thinking

Numerous definitions of visual thinking have been posited by researchers, including the following: [67]) defined visual thinking as the way in which mental images are classified using shapes, lines, colours, and structures to make them meaningful.

Sadiq [52] defined visual thinking as a type of thinking that depends on storing images received by the brain as mental information that works to represent, interpret, and perceive. These are then saved as a cognitive store that can be translated into verbal language.

Al-Jabali and Al-Shuraidah [68] defined visual thinking as a set of skills that enable students to recognise visual forms represented in drawings, pictures, and tables by reading, analysing, understanding, and realising the relationships between them and incorporating them into their cognitive structures.

2) The importance of visual thinking

Visual thinking skills have acquired special importance in the field of teaching and learning mathematics [42, 52, 69], and can be summarised in the following points: Firstly, developing the learner's ability to understand the visual messages surrounding them at a faster rate. Secondly, helping students understand, organise, and synthesise mathematical information, and assisting them to develop the ability to innovate and produce new ideas. Thirdly, attracting students' attention, including visual forms of verbal texts. Fourthly, paving the way for practising different patterns of thinking such as critical and innovative thinking. Fifthly, helping students understand abstract concepts and the processes associated with them. Sixthly, linking ideas and information to visual images and forms, which facilitates learners' comprehension and understanding. Seventhly, developing students' ability to visualise along with their spatial ability. Eighty, improving the quality of learning and accelerating interaction between students, which makes learning lively and active.

We conclude from the above that converting educational material from verbal language to visual language plays an important role in forming positive attitudes that helps learners understand. This provides them with an opportunity to present new ideas that will motivate them to be creative and innovative in solving problems.

3) Visual thinking tools

Visual thinking tools are one of the most important components of visual representation and can benefit both teachers and learners. [6, 70] identified the following thinking tools:

- Images: The image is considered one of the most important features of this era, as it has dominated all cognitive, cultural, and media fields.
- Symbols and signs: Linguistic letters, mathematical and chemical symbols, in addition to various signs, represent tools for visual thinking.
- Schematic and graphic drawings: These are used to convey quantitative information, express it, and compare it easily and simply.
- Geometric shapes: Straight or curved lines come together to form a geometric shape, the construction of which is subject to processes of mental and visual thinking which organise its components of lines, spaces, and colours to create a visual system with meaning which the brain can translate and thus recognise its connotations.
- Three-dimensional objects: Undrawn objects that a person sees in three dimensions (length, width, height) and which are called 3D are considered one of the tools of visual thinking. They are among the most widespread visual tools.

It is evident from the above that the use of images, shapes, and symbols in presenting and designing lessons helps convey ideas in a coherent way, as visual thinking tools contribute to enriching the cognitive abilities and skills of learners, in addition to increasing their creative ability to solve problems. This provides a superior way of storing information, retaining it for a longer period in the brain, and retrieving it when needed.

4) Visual thinking skills

Having reviewed several previous studies, numerous visual thinking skills related to teaching mathematics can be identified. Kousa *et al*. [20, 69] identified the following as the most important:

1) Visual shape recognition and description skill: Denotes the learner's ability to identify the dimensions and nature of the displayed shape.
2) Visual shape analysis skill: Refers to the learner's ability to see relationships in the shape and identify and classify the characteristics of those relationships.
3) Visual shape information interpretation skill: This concerns the learner's ability to interpret the characteristics of each particle, collect information about the parts of the shape, and clarify correspondences and fallacies.
4) Visual shape inference skill: This refers to the learner's ability to understand facts and concepts, principles and laws, and infer new meanings

Based on the above, developing visual thinking skills can be seen to be one of the most important goals in teaching and learning mathematics, as it is a field dominated by abstract concepts and symbols and therefore requires the use of visual forms. It therefore plays a vital role in education, enabling the learner to understand and master these abstractions (Fig. 4).

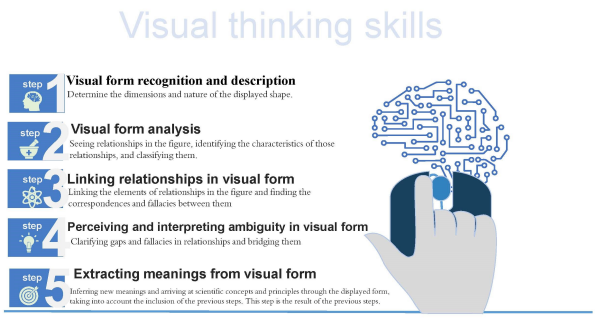


Fig. 4. Visual thinking skills (drawing by researchers).

5) Studies that dealt with visual thinking skills

Mohammed [71] dealt with the effect of using the interactive classroom in teaching geometry on developing academic achievement, visual thinking skills and emotional satisfaction among third-year middle school students. The study sample consisted of (84) students distributed into two groups, one of which was experimental (46) students and the other was a control group (38) student. The researcher reformulated and designed the fifth unit (analytical geometry) for the first semester of the year (2013-2014) in light of the principles and properties of e-learning and innovations in educational technology (in a computerized form) to facilitate its use in the interactive classroom. The results of the study also showed that the experimental group excelled in both the achievement test and the visual thinking skills test and the degree of emotional satisfaction, as there were statistically significant differences in favor of the experimental group.

Hopson [72] conducted a study to identify the impact of a technology-rich learning environment on the development of visual thinking skills and their attitudes towards e-learning. The study was applied to (80) sixth-grade students and (86) fifth-grade students, and a visual thinking test and a questionnaire were applied to them to measure their attitudes towards e-learning. The study concluded that the technology-rich learning environment had a positive impact on the development of fifth-grade students' visual thinking skills, and their attitudes towards e-learning grew. As for sixth-grade students, no significant differences were found.

Yunit *et al.* [73] aimed to develop problem-based learning tools to improve visual thinking and self-efficacy among seventh-grade secondary school students in Indonesia. The researchers developed a problem-based learning model and used the experimental approach based on the control group design with pre- and post-measurement in two different schools. The tools consisted of (worksheets - a visual thinking test - a self-efficacy questionnaire). The results concluded that students' ability to think visually improved and students' self-efficacy in mathematics increased.

Al-Attar [18] aimed to identify the effect of using the generative learning model and visual thinking maps in mathematics for middle school students. The research sample consisted of three equal groups, each of which was (30) students from the first middle school grade. The first experimental group was the geometry content using the thinking maps strategy, the second experimental group used the generative learning model, while the control group was the same content in the traditional way followed in schools, where there were statistically significant differences between the average scores of students in favor of the first experimental group and the second experimental group in visual thinking skills as a whole.

Salem [14] aimed to identify the effectiveness of using visual thinking networks in developing visual thinking skills and academic achievement in mathematics for children with learning difficulties in the primary stage. The study sample consisted of (20) students from the fourth grade of primary school with learning difficulties. The study used the "Teacher's Guide - Thinking Skills Scale - Achievement Scale", where the study found that there were statistically significant differences and a correlation between the average scores of students in the experimental group with learning difficulties who studied using the visual thinking networks strategy in favor of the experimental group.

Ali [44] presented a study to identify the visual thinking skills included in the history book for the seventh grade in Jordan. The researchers used the analytical approach by analyzing the content of the history book for the seventh grade. A list of visual thinking skills was prepared and its validity and stability were verified during the first semester of the year (2021). The results showed that the highest availability of visual thinking skills was in the first semester.

6) Comment on studies that dealt with visual thinking skills

- The current study agreed with previous studies that dealt with visual thinking skills on developing students' academic achievement.
- The current study agreed with previous studies that dealt with visual thinking skills in terms of the approach followed, which is the quasi-experimental approach, such as the studies [18, 21, 71, 72], while it differed with the study [68] in its use of the analytical approach.

The current study also differed from the previous study in the field of visual thinking among students in terms of the tools used for the study, which is the questionnaire tool through the experimental groups, and the control groups such as the studies [14, 18, 71, 72], while it differed from the study

[68], through its use of analytical tools.

7) General comment on all previous studies

- The current study benefited from previous studies in defining the idea in general, choosing the appropriate approach for it, which is the quasi-experimental approach, as well as the appropriate study tools, and in writing the theoretical framework for the topic and discussing the results of the current study, and the extent of agreement and disagreement with the results of previous studies.
- The current study agreed with previous studies in the possibility of employing digital education technology, infographics, and visual thinking in the academic achievement of students at various stages of education (primary, middle, secondary, and university).
- The current study agreed with previous studies that were previously presented in the research topic on the effectiveness of digital education based on infographic technology in developing visual thinking skills and mathematical achievement among middle school students, while it differed from them in the effectiveness of digital education separately from infographic technology, and the effectiveness of education through visual thinking skills.
- The study tools varied in previous studies, while most of them agreed on using the questionnaire, pre- and post-tests, while the current study relied on the mathematical achievement test, and the visual thinking skills test.

Previous studies and the current study have reached the conclusion that digital education, infographic technology, and visual thinking skills have an impact on students' academic achievement at various educational levels. The current study also concluded that there is a strong correlation between visual thinking skills and students' mathematical achievement by consolidating information for a longer period of time. The use of digital education and infographics is one of the modern and good teaching methods that make educational content easier and more interactive for the teacher and the student.

III. Materials and Methods

A. Research Procedures

This section describes the research methodology employed, the sample, and the experimental processing material and research tools used in terms of their construction, including assessment of their validity and reliability. This section also includes a description of the procedures undertaken by researchers in applying the research tools, and the statistical methods used to calculate the reliability of tools and analyze the results.

The current research employed a quasi-experimental method comprising a pre-test and post-test design with two groups (experimental and control). The independent variable was digital education based on infographic technology, and the dependent variable was visual thinking skills and mathematical achievement in the mathematics curriculum for second intermediate grade students (Fig. 5).

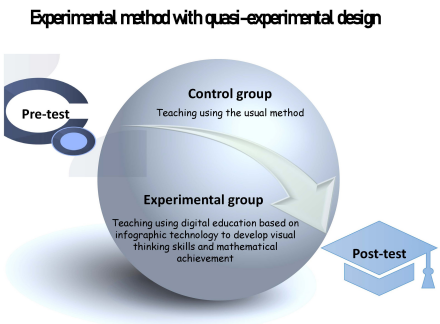


Fig. 5. The quasi-experimental design used in the research methodology (drawing by researchers).

B. Research Community

The research community consisted of all second-grade middle school students in Dammam at the year 1445 AH.

C. Research Sample

The research sample was chosen purposefully, numbering 64 students distributed into two groups. The first group consisted of 33 students who were taught using the experimental method comprising digital education based on infographic technology, whilst the second group, numbering 31 students, were taught using the traditional method.

D. Research Tools

The research utilised the following materials and tools:

The first tool: Visual thinking skills test. Preparing the visual thinking skills test involved the following steps:

1) Determining the objective of the test

The test aimed to measure the visual thinking skills of second-year middle school students through the geometry and spatial reasoning unit.

2) Determining the visual thinking skills for the test

Having reviewed the theoretical literature and educational studies [14, 69], the researchers identified the following visual thinking skills: recognising and describing a shape, analysing it, interpreting it, linking relationships to it, and extracting meanings.

3) Preparing a specification table for the visual thinking skills test

The researchers prepared the specification table according to students' acquisition of visual thinking skills in the geometry and spatial reasoning unit of the mathematics book for the second year of middle school (please see Table 1).

Table 1. Table of specifications for the visual thinking skills test

	Topics	Number of shares	Relative weight of topics	Visual thinking skills					the total	Relative weight of goals
				Recognition	Analysis	Linking relationships	Interpretation	Extracting meanings		
1	Angle and line relationships	5	25%	0	0	1	0	1	2	20%

2	Problem solving strategy	1	5%	0	1	0	0	0	1	10%
3	Polygons and angles	2	10%	0	0	1	0	0	1	10%
4	Congruent polygons	3	15%	0	0	0	1	0	1	10%
5	Symmetry	2	10%	2	0	0	0	0	2	20%
6	Reflection	3	15%	0	0	0	1	0	1	10%
7	Withdrawal	2	10%	0	0	0	1	0	1	10%
8	Rotation	2	10%	0	0	0	0	1	1	10%
	Total	20	100%	2	1	2	3	2	10	100%

4) Formulating the test instructions

After completing the specifications table, the researchers formulated multiple-choice type test questions with four alternatives, so that they measured visual thinking skills. The test in its final form comprised 10 questions, ensuring clarity and brevity in its formulation.

5) Preparing the test in its initial form

The researchers prepared the visual thinking skills test in its initial form, consisting of 10 multiple-choice questions. Each question had four alternatives, one of which was correct, as the test included all previous thinking skills.

6) Test validity

To validate the test, the researchers undertook the following steps:

Validity through arbitrators: To ensure the validity of the test, the test was presented in its initial form to a group of arbitrators and specialists in the field of mathematics curricula and teaching methods. They were asked to express their opinions on the test questions, ensure their clarity and scientific and linguistic soundness, and assess the extent to which they were appropriate for measuring the skills of second-year middle school students. Modifications were made to the initial form based on their suggestions and guidance.

Internal consistency: Based on the results of the survey sample, correlation coefficients were calculated between each paragraph and the total score of the visual thinking skills test, as shown in Table 2.

Table 2. Correlation coefficients

	Correlation coefficient
1	0.566**
2	0.525**
3	0.592**
4	0.571**
5	0.714**
6	0.697**
7	0.571**
8	0.546**
9	0.549**
10	0.549**

7) Exploratory test experience

The test was applied to a sample of 32 students from the second intermediate grade (who were not members of the research sample) with the aim of calculating the ease and difficulty coefficients of the test questions, the distinction coefficients of the test questions, and the test stability coefficient.

8) Determining the test time

The average appropriate time to complete the test was determined by calculating the difference between time at which the first student finished and the time at which the last student finished. This revealed that the total time required for the test was 35 minutes.

9) Estimating the grades and correction method

The estimation of grades in the visual thinking skills test was based on the survey sample, where each question was awarded one point if the correct answer was given, and zero if an incorrect answer was given.

10) Calculating the ease and difficulty coefficients

In light of the results for the survey sample students, the ease and difficulty coefficients for the test questions were calculated. These ranged from 0.40 to 0.59 with an average of 0.49.

11) Calculating the discrimination coefficient

The discrimination coefficient was calculated for each paragraph of the test. This ranged from 0.5-0.9 with an average of 0.7, which indicates good discrimination.

12) Test reliability

The reliability of the visual thinking skills test was verified using the statistical program (SPSS) to calculate the Cronbach alpha reliability coefficient for the test as a whole. Its total value was 0.790, which indicates an appropriate and acceptable value.

Normal distribution: Before choosing the appropriate statistical methods for the processing of the data, the researchers verified the normality of the data distribution to determine the type of statistical methods used. This was achieved by performing the Shapiro-Wilk test, the results of which were as shown in Table 3:

Table 3. Shapiro-Wilk test for the variables under study

Application	**Variables**	**Shapiro-Wilk test**		
		Statistical power	Level of significance	
Pre	Control	0.903	0.009	significant
	Experimental	0.915	0.013	significant
Post	Control	0.948	0.140	Not significant
	Experimental	0.940	0.067	Not significant

It is clear from the results presented in Table 3 that the values of the Shapiro-Wilk test for the variables were at a significance level of <0.05 for the two groups in the pre-application and >0.05 for the two groups in the post-application. This indicates non-normality of the sample distribution in the variables in the pre-application and thus the need to use non-parametric tests, and normal distribution in the variables in the post-application and thus the need to use parametric tests.

13) Final form of the test

The number of items in the final form of the test consisted

of 10 questions distributed over visual thinking skills as follows: Visual shape recognition skill (two questions), Visual shape analysis (one question), Linking relationships in the visual shape (two questions), Perceiving and interpreting ambiguity in the visual shape (three questions), Extracting meanings in the visual shape included (two questions).

14) Controlling research variables

The researchers verified the equivalence of the experimental and control groups through: A. The chronological age of the students taking mathematics. The average age of the students in both groups was between 13.91 to 13.94 years. B. Equivalence of the two groups (experimental and control) in terms of skills: This was verified through the use of a Mann-Whitney test, the results of which are presented in Table 4.

Table 4. Equivalence of the experimental and control groups

Setting type	The group	Number	Arithmetic mean	Standard deviation	Average Rank	Z value	sig value	Significance
Age	Empiricism	33	13.94	0.79	30.84	−0.692	0.489	The two groups are equivalent.
	The control	31	13.91	1.25	34.06			
Pre-application of Visual Thinking Skills	Empiricism	33	3	1.96	33.74	−1.808	0.071	The two groups are equivalent.
	The control	31	3.8	2.91	31.33			

The second tool: Achievement test: Preparing the achievement test involved the following steps:

1) Determining the objective of the test:

The test aimed to measure the mathematical achievement of second-year middle school students taking the geometry and spatial reasoning unit.

2) Preparing a specification Table 5:

Table 5. Specifications table

	Topics	Number of shares	Relative weight of topics	The field			Total	Relative weight of goals
				Knowledge	Application	Reasoning		
1	Angle and line relationships	5	25%	2	1	0	3	30%
2	Problem-solving strategy	1	5%	0	0	0	0	0%
3	Polygons & angles	2	10%	0	1	0	1	10%
4	Congruent polygons	3	15%	0	0	1	1	10%
5	Symmetry	2	10%	0	0	0	0	0%
6	Reflection	3	15%	1	1	0	2	20%
7	Withdrawal	2	10%	1	1	0	2	20%
8	Rotation	2	10%	0	0	1	1	10%
	Total	20	100%	4	4	2	10	100%

3) Preparing the test in its initial form:

The researchers prepared the achievement test in its initial form, which consisted of 10 multiple-choice questions. Each question had four alternatives, one of which is correct.

4) Test validity:

The test was presented to a group of arbitrators to verify its validity. To determine the internal consistency, the correlation coefficient between each paragraph and the total score on the achievement test was calculated, the results of which were as follows in Table 6:

Table 6. Correlation coefficients

	Correlation coefficient
1	0.562**
2	0.516**
3	0.516**
4	0.591**
5	0.629**
6	0.566**
7	0.585**
8	0.563**
9	0.550**
10	0.603**

**Statistically significant at the significance level (0.01).

5) Calculating the ease and difficulty coefficients:

In light of the results of the survey sample students, the ease and difficulty coefficients for the test questions were calculated. These ranged from 0.40 to 0.59 with an average of 0.49.

6) Calculating the discrimination coefficient:

The discrimination coefficient was calculated for each paragraph of the test. This ranged from 0.6-0.9 with an average of 0.75, which indicates good discrimination.

7) Test reliability:

The reliability of the achievement test was verified using SPSS to calculate the Cronbach alpha reliability coefficient for the test as a whole. Its total value was 0.767, which indicates an appropriate and acceptable value.

8) Normal distribution:

Before choosing appropriate statistical methods for the processing of the study data, the researchers verified the normality of the data distribution to determine the type of statistical methods used in the study. This was achieved by performing a Shapiro-Wilk test, the results of which were as follows:

Table 7. Shapiro-Wilk test for the variables under study

Application	Variables	Shapiro-Wilk test		
		Statistical power	Significance level	
Pre-	Control	0.890	0.004	significant
	Experimental	0.878	0.002	significant
Post-	Control	0.948	0.135	Not significant
	Experimental	0.939	0.062	Not significant

It is clear from the results of Table 7 that the values of the Shapiro-Wilk test for the variables were at a significance level of <0.05 for the two groups in the pre-application and >0.05 for the two groups in the post-application. This indicates the non-normality of the sample distribution in the variables under study in the pre-application and thus the need to use non-parametric tests, and its moderation in the post-application and thus the need to use parametric tests.

9) Final form of the test:

The test in its final form consisted of 10 multiple-choice paragraphs as follows: four paragraphs for knowledge, four paragraphs for application, and two paragraphs for inference.

10) Control of the research variables:

The researchers verified the equivalence of the experimental and control groups through (see Table 8):

Table 8. Equivalence of the experimental and control groups

Setting type	Group	Number	Arithmetic mean	Standard deviation	Average Rank	Z value	Sig value	Significance
Pre-application mathematical achievement	Empiricism	33	3.30	2.60	33.74	−0.522	0.602	The two groups are equivalent.
	The control	31	3.58	1.96	31.33			

E. Research Procedures

- The researchers obtained approval from the official authorities to apply the research tools.
- The researchers prepared the mathematical achievement test and the visual thinking skills test, and presented them to a group of arbitrators to elicit their opinions.
- Teaching of the experimental group, numbering 33 students, through digital education based on the use of infographic technology, and of the control group, numbering 31 students, using the traditional method took place, with a total of 20 study periods.

IV. Result and Discussion

This section presents the findings and then interprets and discusses the research results in light of the theoretical framework used in previous studies.

A. Results for the First Question

This question stated: What is the effectiveness of digital education based on the use of infographic technology and its impact on developing visual thinking skills among middle school students?

To answer it, the following hypothesis was tested: No statistically significant difference (>0.05) exists between the average scores of students in the experimental and control groups in the post-application of the visual thinking skills test.

To test this hypothesis, the researchers calculated the value of *t* to compare the average scores of students in the experimental and control groups in the post-application of the visual thinking test, the results of which are presented in the Table 9:

Table 9. Value of t in the post-application of the visual thinking test

	Experimental	Control
Number	33	31
Arithmetic mean	6.7	4.84
Standard deviation	2.311	2.518
Degrees of freedom	62	
Value (t)	−3.078	
eta square	0.13	
Significance level	0.003	

It is clear from the above table that the arithmetic mean of the experimental group's scores in the visual thinking test was 6.7 with a standard deviation of 2.311 and the mean of the control group's scores was 4.83 with a standard deviation of 2.518. The t-value reached -3.078 at 62 degrees of freedom and a significance level of 0.003. This indicates statistically significant differences between the experimental and control groups in the post-application.

These results are consistent with those of studies that have addressed the positive impact of employing infographic technology and its effect on developing thinking [14, 65, 63].

They can be explained as follows. There is an interaction between infographics and an attractive design with bright images and colours that serves to clarify information and enables students to link it using visual senses as a skill (shape recognition, analysis, interpretation, and inference). This enhances learners' focus and attention and develops their skills and creative thinking, enabling them to remember information better, which contributes to improving the quality of education. This seem to be consistent with a number of researchers [16, 52, 57] who found that infographics can make teaching and learning mathematics more fun and exciting due to the effects of colours and the attractive, harmonious images they contain. Numerous learning and message design theories support this idea. For example, Nelson's picture superiority theory describes how individuals learn concepts more effectively by seeing pictures than by perusing content alone since human brains are basically hard-wired for visuals the exceptionally engineering of the visual cortex gives coordinate get to human awareness [16, 28] Pavio's dual coding theory.

B. Results for the Second Question

This question stated: What is the effectiveness of digital education based on the use of infographic technology and its impact on developing mathematical achievement?

To answer it, the following hypothesis was tested: No statistically significant difference (>0.05) exists between the average scores of students in the experimental and control groups in the post-application of the mathematical achievement test.

To test this hypothesis, a t-test was conducted to determine the significance of the differences between the two independent groups by comparing the average scores of students in the experimental and control groups in the post-application of the mathematical achievement development test. The results are presented in the Table 10:

Table 10. Value of t in the post-application of the visual thinking test

Group	Number	Arithmetic mean	Standard deviation	Degrees of freedom	Value (t)	Significance level	Eta square
Experimental	33	6.91	2.283	62	-3.66	0.001	0.18
Control	31	4.61	2.729				

It is clear from the above table that the arithmetic mean of the experimental group's scores in the mathematical achievement development test was 6.91 with a standard deviation of 2.283 and the arithmetic mean for the control group was 4.61 with a standard deviation of 2.729. The value of t was -3.66 at 62 degrees of freedom and a significance level of 0.001. This indicates statistically significant differences between the experimental and control groups in the post-application.

This result is in alignment with previous studies focusing on digital education and mathematical achievement [5, 42, 45, 46].

This can be interpreted as digital education being a type of technology that involves interaction, flexible learning, and expanding the student's knowledge horizons. The ease of conveying information and time and effort saved in learning and teaching all contribute to enhancing students' performance and cognitive achievement. These findings also agreed with [16, 52, 57] regarding the importance of infographics in teaching mathematics.

C. Results for the Third Question

This question stated: What is the correlation between the development of visual thinking skills and mathematical achievement among middle school students?

To answer this, the following hypothesis was tested: No statistically significant correlation (>0.05) exists between visual thinking skills and mathematical achievement.

Table 11. The correlation between the development of visual thinking skills and mathematical achievement

Group		Number	Experimental (visual)	Control (visual)
Tribal	Experimental (Achievement)	33	0.616**	-
	Control (Academic)	31	-	0.429**
After me	Experimental (Achievement)	33	0.818**	-
	Control (Academic)	31	-	0.641**

**Statistically significant at the significance level (0.01).

Table 11 reveals a strong correlation between visual thinking skills and mathematical achievement, which is consistent with the results of studies by Salem *et al*. [14, 18].

The researchers explain the results regarding students' mastery of five visual thinking skills (recognising and describing the visual form, analysing the visual form, linking relationships in the visual form, perceiving and interpreting ambiguity in the visual form, extracting meanings in the visual form) as indicating that such skills play a strong role in consolidating information in the student's mind for a longer period of time by presenting lessons from verbal language to visual language through the use of digital education. This is a strong educational method that works to add fun to learning, making the educational content easier and more interactive for both the teacher and the student. Visual thinking skills have gained special importance in the field of teaching and learning mathematics [42, 52, 69]; for example, in developing the learner's ability to understand the visual messages surrounding them at a faster rate, and link ideas and information to visual images and forms. This facilitates their comprehension and understanding, enabling students to understand, organise, and synthesise mathematical information, and helps them develop their ability to innovate and produce new ideas.

D. Research Limits

The limits of the research were identified as follows:

- Subject Limits: Unit (Geometry and Spatial Reasoning) from the Mathematics Book for the Second Intermediate Grade.
- Spatial Limits: The research was applied in the city of Dammam in the Kingdom of Saudi Arabia.
- Temporal Limits: The research was applied at academic year 1445 AH (Collect data at 25/1/2024).
- Human Limits: The current research is limited to a simple purposive sample of second-intermediate grade students in one of the government schools in the city of Dammam.

V. Recommendations

In view of the findings, the researchers recommend the following:

1) The infographic technology should be included in mathematics curricula at various stages of education.
2) The infographic technology should be included in mathematics in general, and in teaching geometry and Spatial Reasoning in particular.
3) Emphasizing the enhancement of visual thinking skills and the extent to which they are acquired by students in different stages of general education by activating the role of digital education.
4) The stakeholders should take advantage of the findings of this study to encourage teachers to continue using this technology in mathematics education.

VI. Suggestions

1) Evaluate the effectiveness of a proposed programme based on infographic technology and its impact on developing visual thinking skills and mathematical achievement among middle school students.
2) Work on developing curricula in line with the

requirements of digital education to improve learning outcomes.

3) Direct researchers to conduct more studies to determine the effectiveness of digital education based on infographic technology in teaching all subjects.

VII. Conclusion

The current research aimed to identify the effectiveness of digital education based on the use of infographic technology and its impact on developing visual thinking skills and mathematical achievement among middle school students. The results showed a significant difference between the average scores of the two groups in the post-test of achievement in favor of the experimental group. There was also a significant difference between the average scores of the two groups in the post-test of visual thinking skills in favor of the experimental group. A positive relationship was found between the development of achievement development and visual thinking skills that were studied using digital education based on infographic technology. Thus, the research proved the effectiveness of digital education based on the use of infographic technology and its effect on the development of visual thinking skills and mathematical achievement among middle school students.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Authors designed and conducted the research study. Authors analyzed the data. All authors wrote the paper and approved the final version.

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