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| RESEARCH ARTICLE

Investigating the use of Axonometric Projection in Drawing Maps and its Effect on Students' Spatial Ability: A Case Study of Isometrics

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| ABSTRACT
The urgent need to acquire the spatial ability of students of Kabul Polytechnic University, which is considered one of the leading engineering universities in Afghanistan, constitutes the purpose of the research. Therefore, the main question is whether teaching axonometric in the traditional way can meet the main goal stated in the national curriculum, which is to increase the spatial ability of students. To answer this question, this article reviews axonometrics, its types, and application areas. It is worth mentioning that no research has been conducted in Afghanistan so far on the factors that develop students' spatial visualization skills together with applied geometry concepts and other graphic activities that strengthen or limit spatial ability. This article aims to investigate students' spatial visualization skills after completing the first year of teaching engineering graphics and its effect on strengthening spatial abilities, in which the role of axonometric teaching is appropriate. To verify the results of the case study approach, data were collected from the experiences of 7 professors of engineering graphics in the Department of Technical Drawing at Kabul Polytechnic University, and interviews were conducted with 42 first-year students of the Faculty of Civil Engineering at the end of the second semester. Data were collected through an open questionnaire, focused discussion on the topic, arrangement and organization of lessons, observations from the teaching process, and interviews. The results of the exams show that the professors were able to improve the spatial ability of the students by teaching different types of axonometric, especially isometrics.

| KEYWORDS

Axonometric, isometric, spatial ability, axes.

| ARTICLE INFORMATION

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1. Introduction
Axonometric drawing is a subject of engineering graphics that is taught at the end of the first semester and the beginning of the second semester by most students of Kabul Polytechnic University [3]. Accordingly, the teaching of isometric drawing, which is a type of axonometry, involves drawing longitudinal and transverse axes at an angle of 30˚to each other[1]. By placing the lowest point of the map at a certain position, a drawing is determined or a drawing point that must be shown correctly. This topic is usually presented in 2D views and students are asked to convert the 2D map into a 3D map. These views must be drawn on axes that have an inclination of 30˚degrees to the horizon and the x, y, and z axes that together form an angle of 120 degrees. When converting a 2D image to a 3D image, students must combine the retrieved information by searching for relationships between objects and combining them into a graphic skill to create a 3D image[2].

Teaching the ability to understand volumes and spaces using isometric images is one of the most important ways to empower students in engineering and most technical fields. Over the past few decades, many studies have been conducted on the acquisition of various aspects of spatial ability and its cultivation in the research field. Although a clear and developed perspective on the nature of spatial ability has not been formed at the core of these studies, there is consensus on the effectiveness of increasing this skill in understanding volumes and spaces using axonometric images. Among the studies and categories mentioned for spatial ability, the studies of Mayer (1994), (1990), Loman (1988), and Karl (1993) can be mentioned, which are directly related to the basics of axonometric images.

Despite this perspective, many methods and approaches have been developed to strengthen this skill and overcome the weaknesses of students in all disciplines that require a comprehensive understanding of volume or space. However, it seems that in Afghanistan, generally relying solely on the traditional method, especially drawing axonometric images to increase this skill, there is a greater expectation for its significant improvement. Engineering graphics professors, as the only organization that serves to increase this skill in every sense, refer to the chapter and goals set for this topic to justify their educational approaches and methods[3].

Although some professors have recently made innovations to increase students' understanding of two-dimensional and three-dimensional space, in general, comprehensive and developed theories about the development of spatial ability in the context of engineering graphics have not yet been developed at Kabul Polytechnic. In order to develop studies in the field of spatial ability in engineering, the present study, using spatial ability assessment tests, has sought to provide a better understanding of the effectiveness of axonometric training on the spatial ability of engineering students.

Factors that play a major role in reducing the learning of axonometric drawing are the lack of coordination between school and university courses. Usually in Afghanistan, engineering graphics courses are not included in the general school curriculum, and students who enter educational institutions after passing the entrance exam, including engineering universities, face problems when drawing isometrics.

These concerns are repeatedly reflected in the annual report prepared by the Department of Descriptive Geometry and Technical Drawing, and suggestions have also been made to address them. One of the topics of the report is that students have poor performance in isometric drawing; that is, 80 percent of the results of the second semester exam confirm this issue. In his studies in 2015, Sutsaka also mentioned the same concern that many learners have poor performance in the second semester due to the inability of learners to draw general plans and isometric drawings, which are chapters of graphics courses and constitute approximately 65 percent of the second semester program. As a result, this article, following the study, examines the understanding and importance of engineering graphics for axonometric drawing and, in a case study, explains isometric learning and how to teach it, as well as the concepts and problems in the way teaching isometric drawing and its application in different fields.

2. Research Methodology

This research was conducted using and reviewing national and international authoritative books, as well as by studying similar articles, and referring to engineering graphics journals on the subject, as well as analyzing the experiences of professors of the Department of Descriptive Geometry and evaluating the results of questioning professors and students of engineering and industrial and civil buildings, during one semester by arranging single and open-ended questionnaires on the use of axonometric images to acquire spatial ability. In addition, the research was also conducted with a qualitative research approach. According to Bandari (2020), qualitative research involves the collection and analysis of non-numerical data. This approach is mainly used because of its ability to gather deep insights into a topic and seek its solution. The purpose of this study was to obtain students' understanding of engineering graphics and isometric drawing and how to learn and memorize them, and the best qualitative method for collecting such data is through verbal interaction with participants to measure the teaching of isometric images.

3. Theoretical framework of the research

Orthographic projection of an object (front, horizontal, and side view) along with sections and cross-sections provides the possibility of imagining the shape, sizes of its visible and hidden parts. However, orthographic projection lacks the necessary clarity and prominence, that is, it does not present the images as clearly and clearly as it should be [4]. Therefore, in technology, there is a need for such images that contain special clarity and prominence and at the same time reveal the relative sizes, shape of the object, and a complete image and visualization. Such prominent images of the object are called axonometric projections, which are obtained by projecting it parallel to a projection plane along the corresponding orthographic axes [5].

In Figure (1), point A, which is one of the corners of the cube, is shown together with the image of the cube in the orthographic coordinate system. The vector S determines the direction of projection in the image plane Π′ [7,8]. To obtain point A in axonometric projection, we draw a drawing radius (parallel to the vector. $\vec{S}$ through the said point and obtain its intersection with the plane Π' at point A'. The aforementioned drawings show that in the given direction of projection, each spatial point in the projection plane corresponds to a specific point, Figure (1).

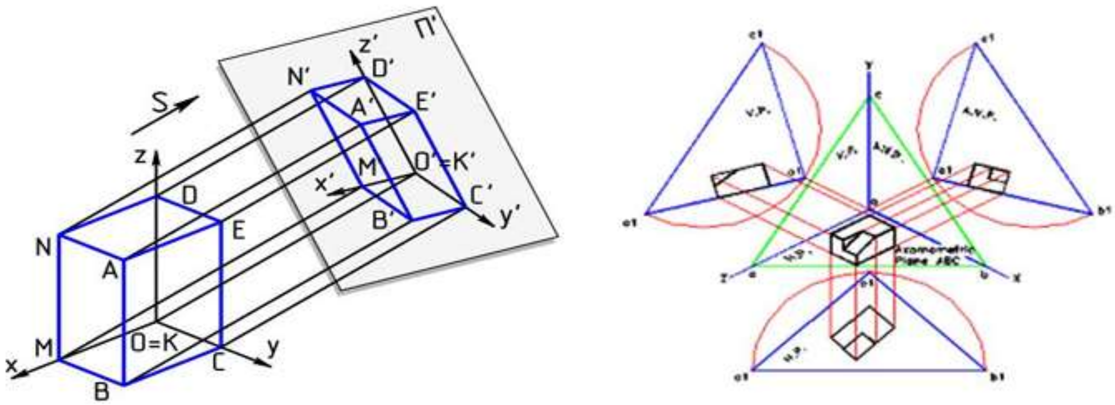

Figure 1. Examples of 3D axonometric layouts commonly used in engineering drawings[7],[8]

But as it turns out, the inverse operation is not possible. This means that every point A' in the plane Π' corresponds to every drawn radius AA'. In order to eliminate this defect and ensure mutual coordination between spatial points and image plane points, they act as follows: in the Π' plane, not only point A but also one of the vertical projection points (usually horizontal projection B) are projected as well [4]. The axonometric projection B' is the horizontal projection of point A and this point is also called the second projection. The aforementioned term (second projection) indicates that point B' is obtained as a result of performing two successive projections. From the study of Figure (1), it can be seen that: if the XYZ coordinate line, the direction. $S^{\rightarrow}$and the Π' plane are given, then the axonometric projection of the point and its second projection determine the position of the same point in space simultaneously.

Through the second projection B^', a line parallel to the direction$S^{\rightarrow}$ is drawn through point A, given at the intersection of the said line with the XOY coordinate plane, the horizontal projection B of point A is obtained. The spatial position of point A It is formed by the intersection of two straight lines AA' and BA, the first straight line from A' parallel to $S^{\rightarrow}$ and the second straight line through point A' perpendicular to the XOY plane [4].

In the Π' plane of Figure (1) axonometric projection of the quantities of the axes of the characteristics in space with the length of their projections, the ratio of the deviation that occurs is not equal to each other. The deviation of the segments of the coordinate axes during their projection in the Π' plane is determined by the coefficients (deviation index).

The deviation coefficients are the ratio between the length of the axis line segment in the image plane to its real length. Thus, the deviation coefficients in the X' axis, k = (O' X') / OX, Y', m = (O' Y') / OY and Z', n = (O' Z') / OZ, which is also called the axonometric scale deviation [4].

In 1853, a German scientist named Pohlke conducted studies on axonometric images, the first proven results of which were published in 1864, which are called the fundamental theorem of axonometry or Pohlke's theory. The following results are obtained from the study of the aforementioned theory [9].

Axonometric maps and images are reversible.

The axonometry of a point and its second projection determine the positions of the point in space as a complement. Axonometric projections are reversible only if the axonometric exists in the main direction of measuring the shape and coefficients or deviations in the mentioned directions.

In drawing axonometric maps and images, the existence of axes and axonometric scales are considered to be the main condition. Types of axonometries in terms of deviation coefficients and direction of projection, if the position of the axonometric projection plane Π' and the direction of projection$S^{\rightarrow}$ change, the quantity of the angle φ and also the quantities of the angles α, β and γ between the axonometric axes change, Figure (2).

From the point of view of the projection angle φ, axonometric projection is divided into two types: vertical projection and oblique projection.

Vertical projection φ=90°is widely used in civil engineering drawings and mechanical engineering drawings.

Oblique projection $\varphi \neq 90°$is considered a general form of axonometric projection. This type of axonometric projection is used in the image of engineering and construction drawings, drawing volumetric graphs and planning geological maps, etc. From the point of view of the quantity of coefficients or deviations, vertical and oblique axonometric projections are divided into three types[4].

Isometric - the deviation coefficients in all three axes are equal (k=m=n).

Dimetric - the deviation coefficients in only two axes are equal (k=m ≠n)

Trimetric - the deviation coefficients in three axes are different (k≠ m ≠n).

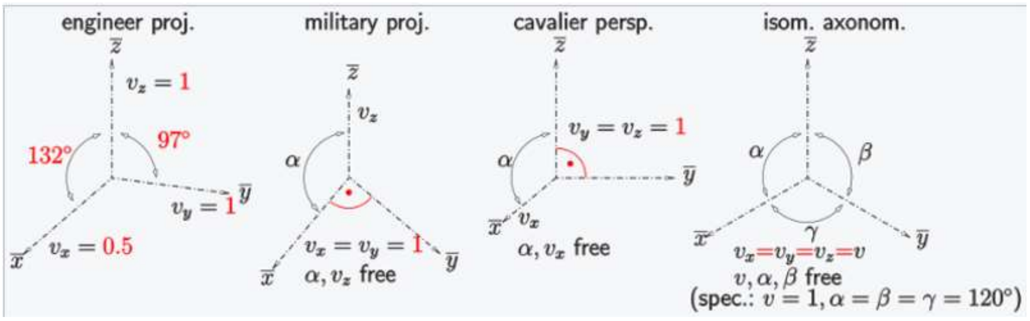

Figure 2. Axonometric axes, angles, and deviation coefficients [16]

In Figure (2), the angle between the axes in all three cases is graphically depicted. In addition to standard axonometric, there are other types of axonometries, the technical specifications and coefficients of which are given in Table (1), and they are used in different sections when necessary.

Table 1. Angles between axes and deviation coefficients for all axonometric types [16]

<table>
<tr><th>Name or property</th><th>$\alpha = \angle\bar{x}\bar{z}$</th><th>$\beta = \angle\bar{y}\bar{z}$</th><th>$\gamma = \angle\bar{x}\bar{y}$</th><th>$\alpha_h$</th><th>$\beta_h$</th><th>$v_x$</th><th>$v_y$</th><th>$v_z$</th><th>$v$</th></tr>
<tr><td>Orthogonal, orthographic, planar</td><td>90°</td><td>0°</td><td>270°</td><td>0°</td><td>270°</td><td colspan="2">v</td><td>0%</td><td>any</td></tr>
<tr><td>Trimetric</td><td rowspan="6">90° + α_h</td><td rowspan="5">90° + β_h</td><td rowspan="5">360° − α − β</td><td rowspan="4">any</td><td rowspan="4">any</td><td rowspan="2">any</td><td>any</td><td>any</td><td rowspan="3">any</td></tr>
<tr><td>Dimetric</td><td colspan="2">v</td></tr>
<tr><td>Isometric</td><td colspan="3" rowspan="2">v</td></tr>
<tr><td>Normal</td><td>100%</td></tr>
<tr><td>Oblique, clinographic</td><td>< 90°</td><td>< 90°</td><td rowspan="3">any</td><td rowspan="3">any</td><td rowspan="3">any</td><td>$\tan(\alpha_h)$</td></tr>
<tr><td>Symmetric</td><td>α</td><td>360° − 2·α</td><td>< 90°</td><td>α_h</td><td rowspan="2">any</td></tr>
<tr><td>Equiangular</td><td colspan="3" rowspan="3">120°</td><td colspan="2" rowspan="3">30°</td></tr>
<tr><td>Normal, 1:1 isometric</td><td colspan="3" rowspan="3">v</td><td>100%</td></tr>
<tr><td>Standard, shortened isometric</td><td>$\sqrt{\frac{2}{3}} \approx$ 81%</td></tr>
<tr><td>Pixel, 1:2 isometric</td><td colspan="2">116.6°</td><td>126.9°</td><td colspan="2">$\arctan(v)$</td><td>50%</td></tr>
<tr><td>Engineering</td><td>131.4°</td><td>97.2°</td><td>131.4°</td><td>$\arccos(\frac{3}{4})$</td><td>$\arcsin(\frac{1}{8})$</td><td>50%</td><td colspan="2" rowspan="3">v</td><td rowspan="8">100%</td></tr>
<tr><td>Cavalier</td><td rowspan="2">90° + α_h</td><td rowspan="7">90°</td><td rowspan="2">270° − α</td><td rowspan="2">any</td><td rowspan="7">0°</td><td>any</td></tr>
<tr><td>Cabinet, dimetric cavalier</td><td>< 100%</td></tr>
<tr><td>Standard, isometric cavalier</td><td rowspan="2">135°</td><td rowspan="2">135°</td><td rowspan="2">45°</td><td colspan="3">v</td></tr>
<tr><td>Standard 1:2 cabinet</td><td rowspan="3">50%</td><td colspan="2" rowspan="4">v</td></tr>
<tr><td>30° cabinet</td><td>116.6°</td><td>153.4°</td><td>$\arctan(v_x)$</td></tr>
<tr><td>60° cabinet</td><td>153.4°</td><td>116.6°</td><td>$\text{arccot}(v_x)$</td></tr>
<tr><td>30° cavalier</td><td>120°</td><td>150°</td><td>30°</td><td>any</td></tr>
<tr><td>Aerial, bird's eye view</td><td colspan="2" rowspan="2">135°</td><td rowspan="5">90°</td><td colspan="2" rowspan="2">45°</td><td colspan="2">v</td><td>any</td><td rowspan="2">100%</td></tr>
<tr><td>Military</td><td colspan="3" rowspan="4">v</td></tr>
<tr><td>Planometric</td><td rowspan="3">90° + α_h</td><td rowspan="3">180° − α_h</td><td rowspan="3">any</td><td rowspan="3">90° − α_h</td><td>any</td></tr>
<tr><td>Normal planometric</td><td>100%</td></tr>
<tr><td>Shortened planometric</td><td>$\frac{2}{3} \approx$ 67%</td></tr>
</table>

All of the options included in Table (1) can be used to draw axonometric images, but the drawings depicted in Figure (3) are the most common.

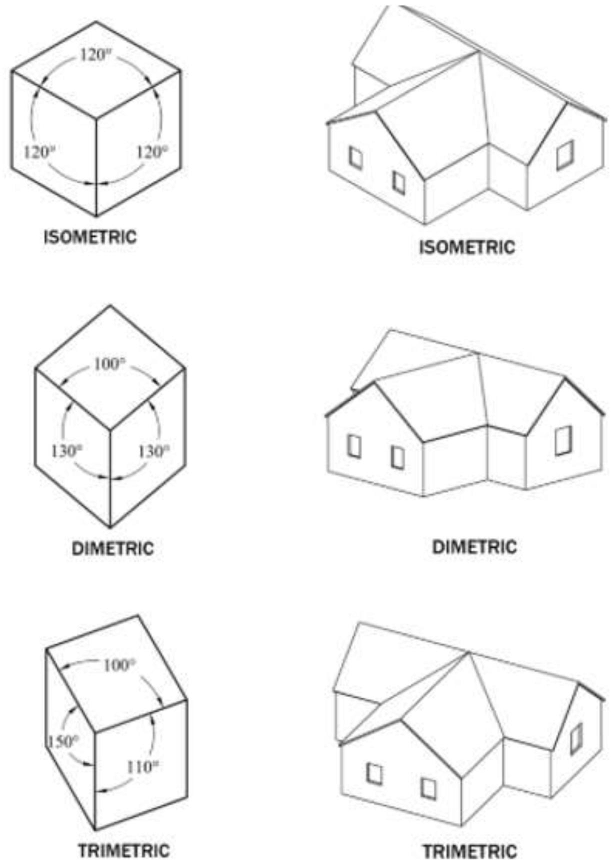

Figure 3. Types of axonometric images and their axis formation

4. The Importance and Use of Isometric Images

In recent years, several educational articles have been presented on the importance of spatial ability that is directly related to isometric images. Among them, we can mention the article by Smith (1964). He concluded that there are 84 jobs in which spatial ability plays a significant role. The results of Maier's (1994) research showed that spatial ability, especially the ability to "mental rotation", is of particular importance for technical professions such as engineering. In a study conducted by Norman (1994), the result was that the level of spatial ability of an individual is the best estimator of the position of individuals in the ability to interact and use computers that have a regular relationship with three-dimensional shapes.

Barke (1993) concluded in his studies that strong spatial abilities are necessary and essential for understanding structural chemistry and basic chemistry. McKim points out that the ability to think visually is necessary not only for artists but also for those who serve in scientific and technical professions such as medicine. He gives several examples of discoveries or technological advances throughout history that were made through vision and visualization and had a long-lasting impact on society, such as Fleming's discovery of penicillin, Kekule's discovery of the structure of the benzene ring, Watson's discovery of the helix structure of DNA, and inventions such as the fluorescent lamp and Tesla's A-C generator. He also claims that Einstein continued to use his thinking through visual thinking and images, noting that it was difficult for Einstein to fit thoughts into words as a secondary structure.

An isometric view is the most common type of graphic image in engineering science and is a type of axonometric view. To draw this view, the object is rotated 45°about its vertical axis and tilted forward approximately 35.264° (exactly the arctan1/(√2)) Figure (4). In this way, the angle between the ages of the object in the image will be 120°. As a result, the image will have the same scale along all three axes and the size ratio will be maintained. As a result of this type of rotation of the object, the size ratio in the image will be 0.815 times the size of the object. This can also be defined using mathematical techniques [23]. For scientific purposes that require direct measurement. It is enlarged again to a scale of 1:1 [1].

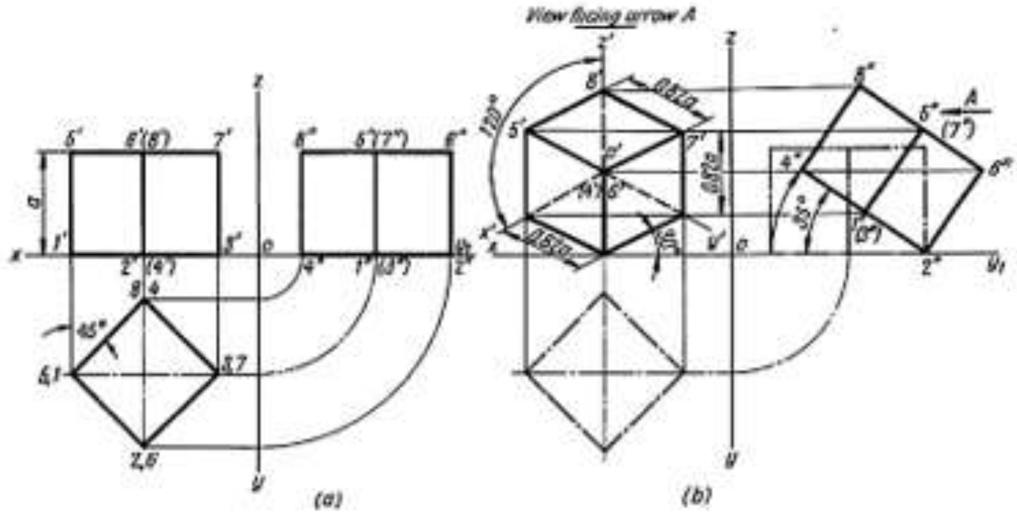

Figure 4. Obtaining the angle between the axes and the deviation coefficients graphically in isometric [11]

When drawing isometric drawings, special attention should be paid to the selection of the principal axes so that the most information is obtained with a natural and intuitive appearance and with the least need to draw hidden lines with other views[1]. Drawing isometric drawings today is usually done with the help of code software. However, drawing the isometric overview by hand can be useful and useful, especially in the early stages of design[1]. Isometric drawings can be drawn by hand on isometric paper that has grid lines parallel to the principal axes of the image (depth, height, and width)[3]. In isometric drawings, all lines that are parallel to the isometric axes are called isometric lines[2]. However, all non-isometric lines do not appear at their actual size and are more difficult to draw. Due to this type of scaling, circular shapes of the object will appear as ellipses in the image[1]. Despite various techniques and tools, drawing ellipses can be difficult. For accurate placement, the perimeter square/rectangle of a circle/ellipse can be used to find the exact location of its larger diameter and then draw the ellipse. Other irregular shapes can also be drawn by defining a square grid on the surface of the shape and transferring the points of contact of the shape with the grid to the equivalent grid in the image[4]. Isometric drawings are one of the key tools in all engineering disciplines such as engineering, construction, mechanical engineering, volume and estimation, and even video games. These drawings allow designers and engineers to display three-dimensional objects in a two-dimensional form on a plane while maintaining relative dimensions. Given the increasing need for accurate and realistic designs in various industries, isometric drawings have become an essential tool. This article aims to comprehensively review isometric drawings, from the history and principles of drawing to its applications, advantages, and disadvantages, as well as introducing various tools and software used to draw this type of images. By studying this research, you will gain a better understanding of the importance and role of isometric drawings in design and engineering as will increasing of spatial ability.

Figure 5. Isometric image with traditional tools

An isometric drawing is a type of graphic representation in which three coordinate axes representing length, width, and height are placed at an angle of 120 degrees to each other. These types of drawings allow the three dimensions of an object to be displayed simultaneously and without distortion in relative dimensions. In other words, in isometric drawings, length, width, and height are scaled to the same size, which makes objects appear more realistic and understandable[11]. In the past centuries, during the years before Christ, industrial parts and equipment were shown and introduced using drawings that were not completely clear and did not have rules that everyone could understand, and they faced problems when reading the drawings until Mr. Leonardo da Vinci, an Italian painter and sculptor (1459-1516), presented writings that showed the rules of three-dimensional physical design on a two-dimensional surface, which however made the drawings a little more clear and understandable. Then European scientists and mathematicians followed his work until Gaspard Mange from France introduced drawing geometry in 1798, which laid the foundation for the isometric drawing certification process and today the same principles are still followed. The use of isometric drawings goes back centuries. This type of representation is also seen in ancient arts and ancient architectural designs. But its widespread and scientific use in engineering and architecture reached its peak in the 19th century with industrial advances. Isometric drawings were used as an important tool for design and production during this period and were able to meet the precise and complex needs of various industries. Figure (5).

To draw an isometric drawing, we first draw three main axes that are at an angle of 120 degrees to each other. These axes represent length, width, and height, respectively. We then specify the dimensions of the object on these axes and, by connecting the various points, we display the three-dimensional shape of the object in two dimensions. One of the important features of isometric drawings is that all parallel lines in the three-dimensional object are also displayed as parallel lines in the two-dimensional drawing[11].

4.1 Use of Isometric Images in Architecture

In 2010, Ms. Yagmur, E. K. from Georgia Tech University, expressed the importance of axonometric visualization in architecture as follows: Many engineers have expressed their opinions about the various aspects of isometric visualization affecting their design process, especially when they are comfortable working with 2D drawings of their design. Understanding information about a building through 2D drawings and images generally indicates that every architect must visualize the building in 3D in his mind by looking at 2D drawings and through this, that is, visualize the building in 3D, easily understand the different dimensions of that building. This research in the field of architectural education has shown that the "ability to visualize spatially" plays an important role in carrying out engineering design. As "spatial ability" is known as an essential skill for engineers in 3D visualization. In this field, research has been conducted that confirms the direct relationship between 3D visualization and spatial ability using various tests [16]. Martom Brosamle and Christoph Holsecher in 2007, in their article on engineers' drawing abilities, entitled "Engineers look at the building from the perspective of users", introduce the term as navigation. In defining this term, they claim that "navigation" is used in the field of engineering design and refers to the ability to "spatial orientation" that leads to the correct design of access routes in the building. With the help of the correct access routes, we will be able to easily get to the desired route/location from where I am.

In architecture, isometric drawings are an important tool for representing buildings and structures. These drawings allow architects to present their designs in a clear and understandable way to clients and builders. Because of their three-dimensional representation, isometric maps can display intricate details, such as precise size and proportions, that are difficult to discern in conventional two-dimensional maps [9].

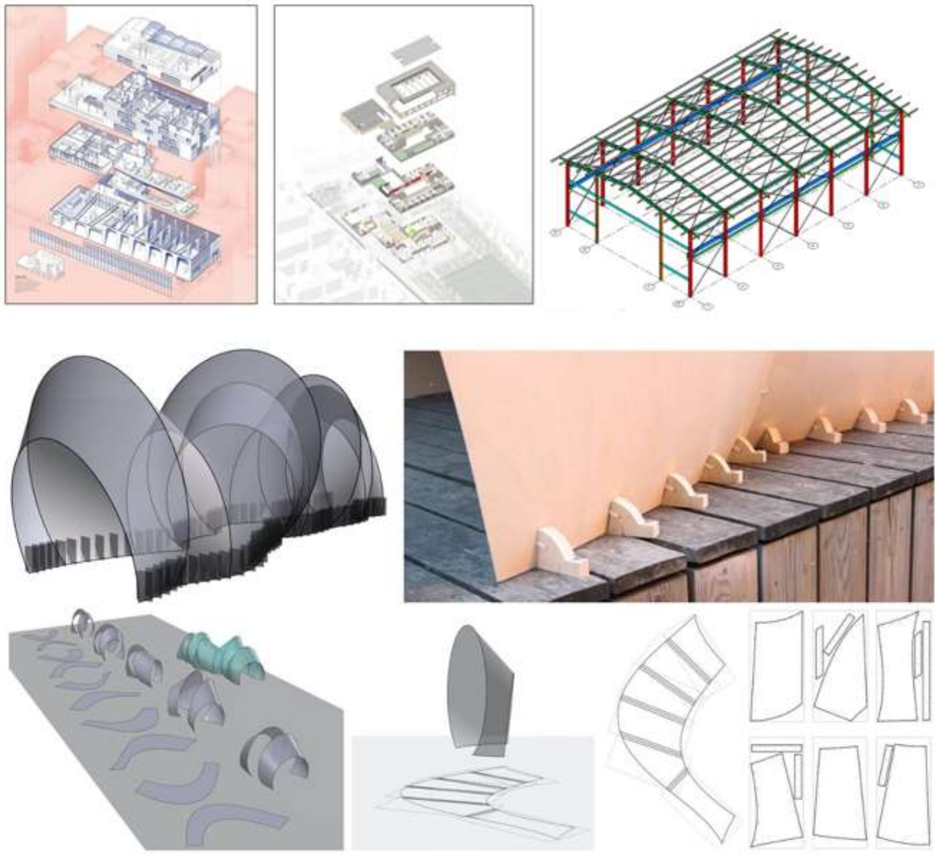

Figure 6. Shows examples of 3D architectural isometric drawings commonly used by American and European architects[9, 10, 24]

This type of representation helps architects visualize their ideas in a realistic and visual way and also identifies potential design problems before construction. In addition, isometric drawings allow architects to more accurately depict the interactions between different building components, which is very useful for coordination between different teams on large projects. Isometric drawings are also used in architectural software Figure (4).

4.2 Use of Isometrics in Mechanical Drawings

In mechanical engineering, isometric drawings are used to design and display machinery and industrial parts. These drawings help engineers to accurately display the various components of a machine while maintaining relative dimensions. This helps manufacturers to build and assemble parts correctly. Isometric drawings in mechanical engineering are also used to simulate the operation of machinery and to check their efficiency and safety. Using these drawings, engineers can identify the strengths and weaknesses of a design before it is actually built and make the necessary changes if necessary. This process helps to reduce costs and increase the quality of the final products Figure (7).

Figure 7. Isometric drawing of machine

4. 3 Water Supply Drawings

Piping systems and water supply lines, which are often complex and intertwined, are drawn on two-dimensional drawings that can be read and understood correctly, using a series of principles called isometric piping drawings. In order for students and a skilled person to be able to read and understand a piping drawing correctly, they must benefit from the science of reading isometric piping drawings. Changing the direction of the pipe or offset, in a piping system, often changes the direction of the path of a pipe, so in order for this change of planes to be implemented in a two-dimensional drawing. A series of rules and regulations must be followed so that it can be drawn correctly in a two-dimensional drawing. Having a basic knowledge of trigonometry and trigonometric theorems such as the Pythagoras is very important for reading isometric piping drawings Figure (8).

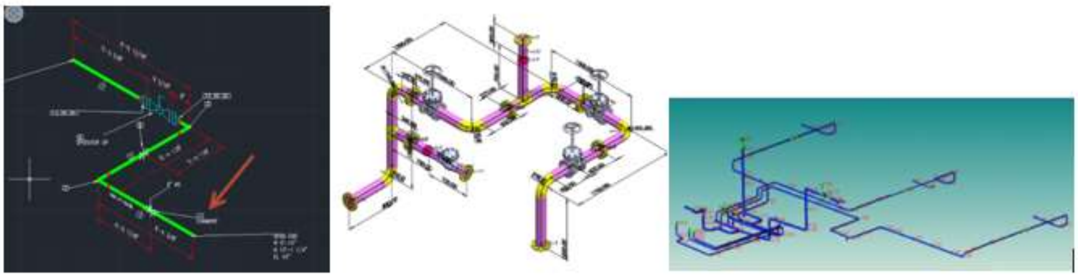

Figure 8. Piping isometric

4.4 Video Games

In the gaming industry, isometric maps are used to design game environments and maps. These maps allow game designers to display 3D environments in a 2D and understandable way. Many popular old games and even some modern games use this type of representation. Isometric maps in video games help designers to display the game space in a more attractive and realistic way and provide a better experience for players. This type of representation is especially effective in strategy and role-playing games, as it allows players to easily manage movement and interaction with the game environment. In addition, isometric maps help game developers design graphical details more efficiently and at a lower cost[16].

Figure 9. Isometric use in computer games

4.5 Urban Planning and Urban Development

Isometric projections are also widely used in urban planning and urban development. These maps allow urban planners and planners to accurately and realistically draw comprehensive urban plans, including streets, parks, commercial and residential buildings. Using isometric maps, it is possible to clearly display the connections and interactions between different urban components and predict and solve potential problems in infrastructure and traffic. These maps also help citizens to better understand urban plans and participate in the decision-making process. In this way, isometric maps are an important tool for sustainable urban development and improving the quality of life in cities.

Figure 10. Urbanization isometric drawing

4.6 Medicine and Medical Engineering

In the field of medicine and medical engineering, isometric drawings are used to design and display medical equipment and prosthetics. These drawings help medical engineers and doctors to display their designs in an accurate and understandable way. Using isometric drawings, the performance of medical equipment can be simulated and checked and, if necessary, changes can be made. These drawings are also used in the design of prostheses and implants so that they can be produced more accurately and according to the individual needs of patients. In this way, isometric drawings help to improve the quality of treatment and increase patient comfort.

4.7 Transportation and Logistics

Isometric maps are also used in transportation and logistics. These maps help designers and engineers to accurately and realistically draw transportation systems, including roads, railways, and airports. Using isometric maps, the connections between different components of the transportation system can be well displayed and potential problems in traffic and transportation can be predicted and solved. These maps also help logistics planners to optimize the transportation and distribution processes of goods to select the best channel, thus reducing costs and increasing efficiency.

4.8 Art and Graphic Design

Isometric drawings are also used in art and graphic design. These drawings allow artists and graphic designers to present their artwork and designs in a unique and realistic way. Using isometric drawings, it is possible to display the exact details of the designs well, thus creating more unique and impressive artwork. These drawings are especially effective in designing posters, brochure designs, websites, and many other graphic projects. As such, isometric drawings are a useful tool for improving the quality of the design and increasing the visual appeal of artwork.

5. Finding

1. One of the biggest advantages of isometric drawings is their high clarity and accuracy compared to dimensional and trimetric drawings. Because these drawings display three-dimensional objects in a two-dimensional form and maintain relative dimensions, they allow designers and engineers to easily display accurate and complex details.

2. Because they display more realistically than conventional two-dimensional drawings, isometric drawings help audiences to easily understand designs and ideas. This is especially important in presenting architectural projects and designing industrial drawings.

3. Another advantage of isometric drawings is that they allow designers to display three-dimensional objects in a two-dimensional form. This is especially useful in designing machinery and industrial parts.

4. Isometric drawing requires high accuracy and special skills. Designers must carefully calculate angles and dimensions to create an accurate and understandable drawing. This can be time-consuming and difficult.

5. Although isometric drawings allow designers to show intricate details, in some cases some details may be difficult to display. For example, showing objects with complex curves and unusual angles may be challenging in isometric drawings. However, this drawback can be overcome by drawing isometrics using drawing programs such as AutoCAD, Slideworks, SketchUp, and other programs.

6. Conclusion

Isometric drawings, as one of the important tools in design and engineering, allow designers and engineers to accurately and realistically display three-dimensional objects in a two-dimensional format. Due to their high clarity and accuracy, ease of understanding, and three-dimensional display, these drawings are used in various fields such as architecture, mechanical engineering, industrial design, and game development. However, drawing isometric drawings requires high precision and special skills and may have limitations in displaying certain details. Various tools and software such as AutoCAD, SolidWorks, and SketchUp help designers and engineers create isometric drawings easily and with high accuracy. Considering the importance and wide applications of isometric drawings, it can be concluded that these types of drawings are considered one of the key tools in design and engineering and play an important role in the progress of various industries.

7. Recommendations

1. It is recommended that additional teaching opportunities be added to the National curriculum for students to strengthen spatial ability training, in which the role of isometrics is prominent and useful.

2. Teaching isometric learning techniques with the help of both options with traditional tools and later with computers should be included in the conventional programs of the Polytechnic University.

3. To improve the spatial ability of students in all engineering disciplines, especially students of the Faculty of Civil Engineering and Mechanical Engineering, the training of drawing plans with isometric skills should be more focused because this project is widely used by engineers in the United States, Russia, Europe, and other countries. Teaching it with practical concepts will increase the mobility of Afghan engineers and technicians and make their spatial ability compatible with other engineers.

References

[1] Alcaniz, M; J.D; Contero, M; Otey. (2014); Visualization and Engineering Design Graphics with Augmented Reality second: Edition.

[2] Alonzo, A. C. (2002), Evaluation of a model for supporting the development of elementary school teachers' science content knowledge. Proceeding of the Annual international Conference of the Association for the Education of Teachers in Science.

[3] Arnold E (1918): Proof of Pohlke's Theorem and Its Generalizations by Affinity, American Journal of Mathematics, Vol. 40, No. 4 (Oct., 1918), pp. 366–374.

[4] Bogolyubov, S.. and Voinov A. (1987) Engineering Drawing, MIR Publises, Moscow,1987.

[5] Brailov A Y (2016). Engineering Graphics: Theoretical Foundations of Engineering Geometry for Design . Springer. ISBN 978-3-319-29717-0.

[6] Brailov, A Y (2016). Engineering Graphic: Theoretical Foundations of Engineering Geomety for Desing.Springer, ISBN 978-3-319-29717-0.

[7] Danishyar, N (1368); Descriptive Geometry, Kabul Polytechnic University: Kabul.

[8] Engineering Graphics – Graphics for Engineers (2017) By: Giesecke, O'Bryant. Dobrovony, etal, Macmillan Publishers, Stipes Publishing Co. ISBN)-12-946329- 2, ISBN 0-87563- 361-7, Also may accessed at: htt://test. Scoilnet. ie/ Res/ paulmcdonnel 130899015624- 2.htm, retrieved September 2017.

[9] Gimena L., Gonzaga P and Gimena F.N (2011). Main axonometric system related views as tilt of coordinate planes, Proceeding of IMPro Ve., 2011, Venice, June 2011, pp 748-752.

[10] Graf .U and Bamer, M (1961). Darstellende Geometrie. Heidelberg; Quelle& Meyer. ISBN 3_494-00488-9.

[11] Gray R. B et al. (2002). Technical Graphics Communication McGraw- Hill Professional, 2002, ISBN 0- 07- 365598-8, p. 330, retrieved: August 2017.

[12] Kabul Polytechnic National Curriculum (2014).

[13] Lazaro, G, Mikel, G, and Pedro, G ; (n.d) Pohlke Theorem: Demonstration and Graphical Solution Department of Projects Engineering. Public University of Navarre.

[14] leopold, C (2005). Geometristche Grundlagen der hitekturdarstellung,Stutt: Kohlhammer Verlag. ISBN 3-17-018489.X.

[15] Marunic-V.G, G. (2014) Improvement and Assessment of Spatial Ability in Engineering Education, Engineering Review .Vol.34.Issue 2.139-150.2014.

[16] Nicilas. L, Alvars. L, and Juan. C. V ; (2023) Seismic Performance Assessment of a Moment- Resisting Frame Steel Warehouse Provided with Overhead Crane" School of Civil Engineering Pontificia Universidad Catolica de Valparasis, Valparaiso 234000, Chile; Nicolas, March 2023.

[17] Philani, B; M (2024) Instructionl Practices by Engineering Graphics and Design Teachers: A Focus on Teaching and Learning of Isometric Drawing Research in Social Social Sciences and Teechnology ., Vol,9,2024 .

[18] Pohlke K: (1876) Zehn Tafeln zur darstellenden Geometrice. Gaertner-Verlag Berlin 1876(Google Bool).

[19] Roberto. N,& Andres.M, (2021), Form descriptive Geometry to Architectural Geometry Contribution by Classic Authors to the Nee Paradigm. University of Seville.

[20] Rouhni.M.(2006).Technical Drawing. Industrial University, Tehran, ISBN 964-7982-28-3.

[21] Sawchuk, S.(2012). Duncan has harsh words for teacher colleges, Retrieved on 20 July 2015 from: http:// blogs. Edweek.org/edweek/teacherteat/10/Duncan_ tea.html.

[22] Schwarz, H. A. (1864) Elementarer Beweis des Pohlkeschen Fundamentalsatzes de Axonometie, J, reine angew, Math, 63, 309- 314, 1864.

[23] Signor, J (2014) Jump up to: a b Signor, Jeremy(2014-12-19)." Retronauts: The Continued Relevance of Isometric Games". usgamer. Net. Gamer Networ. Archived from the original on 2022-09 -25. Retrieved 2017-04-01.

[24] Yasser. O. (2018) Isometric Drawing and The Student of Architecture EI- Gammal,. Vol.13, No, 47, April 2018,584 597.

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