IOSR Journal of Computer Engineering (IOSR-JCE)
e-ISSN: 2278-0661, p-ISSN: 2278-8727, Volume 27, Issue 4, Ser. 4 (July. – August. 2025), PP 10-17
www.iosrjournals.org

On The Contour Lines Modelling By Using Different Computing Engineering Tools: A Didactical Overview

J.F. Cárdenas-Castillo, J.G. González-Hernández, J.R. Hernández-Mendoza, O.A. Gallifa-Elizondo, R. Galindo-Del-Valle, S. González-Torres, J.V. Trinidad-Puente, J. Zamora-Santiago
Tecnm Campus Instituto Tecnológico De Ciudad Madero, México
Universidad Tecnológica De Altamira, México
Tecnm Campus Instituto Tecnológico De Cerro Azul, México

Abstract :
In engineering vector calculus courses, one of the most recommended tools for re-constructing three-dimensional elements is the use of contour lines. This is due to their versatile and simple elements, which allow for appropriate didactic guidance for the assimilation of their underlying concepts. This research article provides three different computational tools for constructing contour lines. These tools were tested with university students and improved their academic performance and understanding of the concepts associated with interpreting curve equations.
Keywords: *Contour lines, vector calculus, three-dimensional elements, academic performance, computational tools*

Date of Submission: 17-08-2025 Date of Acceptance: 27-08-2025

I. INTRODUCTION

The origins of contour lines go back several centuries before modern mathematics and mapping technology; they started as a practical way to show height and depth on a flat sheet of paper. Contour lines are important in engineering and academics because they provide a precise yet intuitive way to represent and analyze three-dimensional surfaces on two-dimensional media, which is essential for design, planning, and teaching. Contour lines are understood across disciplines and countries, in this sense, they represent a universal language, they also provide efficient data compression since a few lines can represent vast terrain features, besides, they provide the foundation for modern tools, they are still fundamental in the era of Geographic Information System (GIS), drones, and Light Detection and Ranging (LiDAR) (the raw data often ends up as contour maps for interpretation) [1-5].

The importance of contour lines deals to several engineering fields, for instance, in civil and geotechnical engineering, contour maps show the slope, elevation, and shape of the land without the need for 3D models, it is also useful for site planning, so engineers can decide where to place buildings, roads, drainage systems, and other infrastructure. Contours allow estimation of earthwork volumes for leveling, excavation, and embankments, they also help in identifying water flow paths and flood-prone areas.

In hydrology and environmental engineering, contour lines are used to map watersheds, design irrigation systems, and plan stormwater management as well as to indicate flow direction and potential erosion zones. In mining, they are useful for pit design, slope stability, and haul road layout, also for determining feasible road or railway gradients [5-10].

In the field of academics, contour lines teach students how to interpret 2D data to understand 3D spatial relationships, also providing foundational knowledge for site analysis and layout. Students can learn to read and produce contour maps from field data. In geography, geology, and environmental science, contour lines are essential for analyzing landforms, tectonic activity, and climate-related phenomena and they also serve as a basis for Digital Elevation Models (DEMs) and computational simulations. In architecture, contour maps help integrate buildings into landscapes. In meteorology, adapted forms of contour lines (isobars, isotherms) teach spatial patterns of climate variables.

Several decades ago, it was difficult for college teachers to transmit their students the understanding of contour lines through a graphical representation, but with the advances of technology, the use of software to create contour line graphics is highly important for college students' understanding because it bridges the gap between abstract concepts and real-world application. For instance, students can see how measured points in the field translate into contour maps. Software can display both the 3D terrain and the 2D contour projection, helping students grasp how elevation translates to lines on a map. Zooming, rotating, and adjusting contour intervals helps students experiment and instantly see the effects [11-16].

Students learn software used in professional engineering and surveying, such as AutoCAD Civil 3D, ArcGIS, QGIS, or MATLAB. They practice importing, processing, and cleaning survey data before generating contour graphics. Nearly all real-world contour work today is computer-assisted; learning it in college ensures smooth transition to jobs. Manual contour drawing can introduce distortions; software ensures mathematically precise interpolation. Students can go from raw GPS or total station data to a finished contour map in minutes, allowing more time for analysis. It is easy to change scale, intervals, colors, and formats for different learning purposes. Students can simulate terrain modifications (cut and fill, flooding, road alignment) and instantly visualize the impact.

Software allows students to layer other spatial data (soil type, vegetation, water flow) over contour lines for deeper analysis [17-20]. In summary: for college students, software-generated contour lines are not just a convenience, but they're a core educational tool that improves understanding, builds professional skills, ensures accuracy, and fosters analytical thinking).

II. TREE-DIMENSIONAL GRAPHS OF THE EQUATIONS

Let consider the specific case of the following surfaces in the space as shown in equations (1-6):

$$z = \sqrt{25 - x^2 - y^2} \qquad (1)$$

$$z = \sqrt{1 - \frac{x^2}{9} - \frac{y^2}{4}} \qquad (2)$$

$$z = \sqrt{x^2 + y^2} \qquad (3)$$

$$z = x^2 + y^2 \qquad (4)$$

$$z = \sqrt{x^2 + y^2 - 1} \qquad (5)$$

$$z = x^2 - y^2 \qquad (6)$$

A traditional method for 3D shapes is the use of traces, for instance, in Eq. (1) if x=0. The trace yz is indicated in Eq. (7); if y=0, the trace xz corresponds to Eq. (8). If z=0, then Eq. (9) is derived (trace xy), but nowadays these 3D surfaces can be easily plotted using software. Figs. 1-6 represent the graphics in Winplot, MATLAB, and GeoGebra of Eqs. (1)-(6) respectively. Fig. (1) represents a semi-sphere of radius r=5. In Winplot, the 3-D option is chosen, and then the corresponding equation is typed. In MATLAB, the appropriate commands are used. In GeoGebra, the 3D Calculator option was chosen, and then the equation was written. It is important to be careful with the function domain to avoid imaginary numbers.

$$z = \sqrt{25 - y^2} \qquad (7)$$

$$z = \sqrt{25 - x^2} \qquad (8)$$

$$x^2 + y^2 = 25 \qquad (9)$$

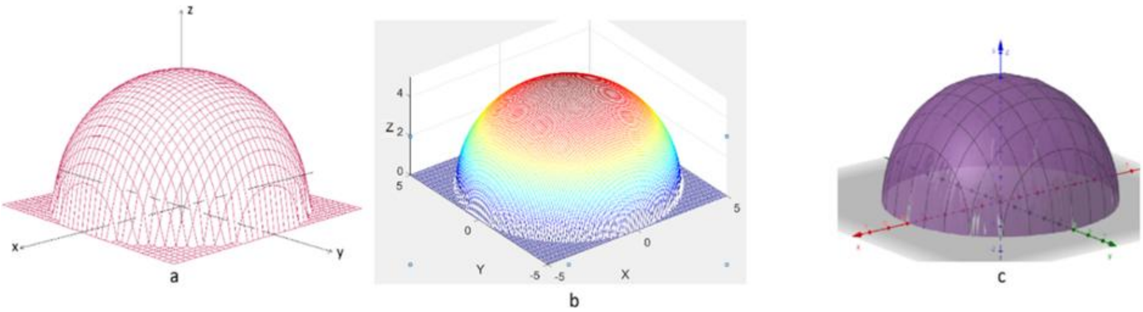

Figure 1. 3D graphic of Eq. (1) in (a) Winplot, (b) MATLAB, (c) GeoGebra

Fig. 2 shows the 3D graph of a semi ellipsoid, which is represented in the Eq. (2). The trace xy is an ellipse accordingly to Eq. (10).

$$\frac{x^2}{9} + \frac{y^2}{4} = 1 \qquad (10)$$

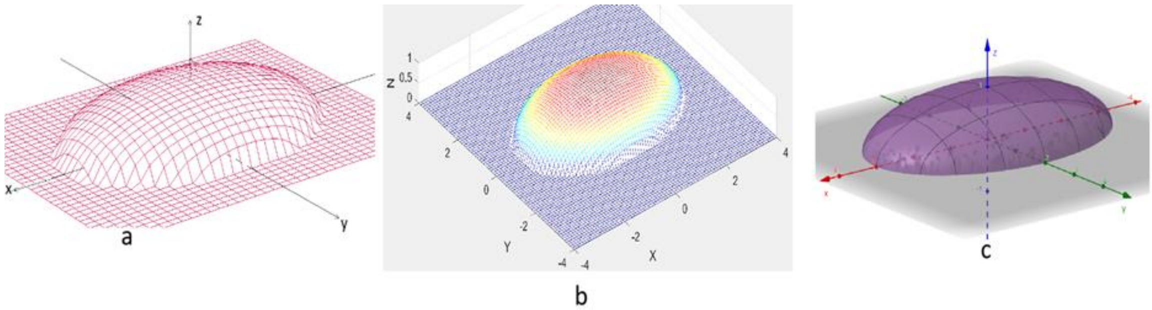

Figure 2. 3D graphic of Eq. (2) in (a) Winplot, (b) MATLAB, (c) GeoGebra

Fig. 3 shows the 3D graph of a circular cone, which is represented in the Eq. (3). The associated contour lines are circles of different radii.

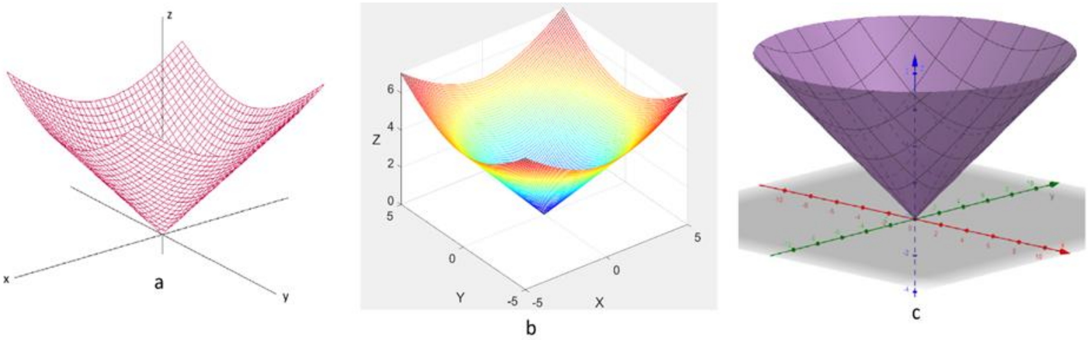

Figure 3. 3D graphic of Eq. (3) in (a) Winplot, (b) MATLAB, (c) GeoGebra

Fig. 4 represents the 3D graph of a circular paraboloid, which is represented in the Eq. (4). The xz and yz traces are parabolas.

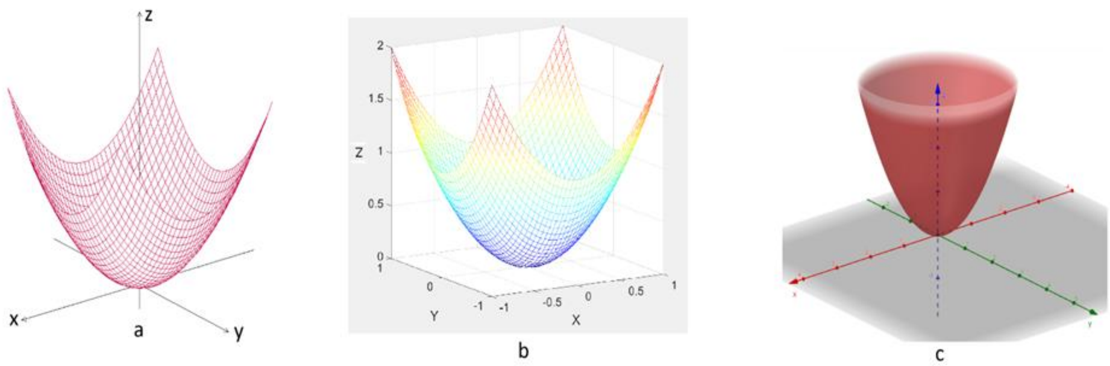

Figure 4. 3D graphic of Eq. (4) in (a) Winplot, (b) MATLAB, (c) GeoGebra

Fig. 5 represents the 3D graph of a hyperboloid of 1 sheet, which is indicated in the Eq. (5). The xz and yz traces are hyperbolas, as shown in Eqs. (10) and (11) respectively.

$$x^2 - z^2 = 1 \qquad (11)$$
$$y^2 - z^2 = 1 \qquad (12)$$

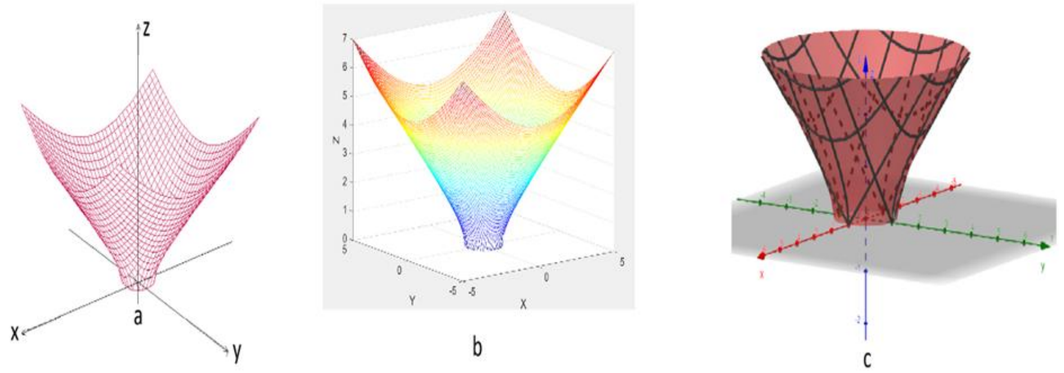

Figure 5. 3D graphic of Eq. (5) in (a) Winplot, (b) MATLAB, (c) GeoGebra

Finally, Fig. 6 represents the 3D graph of a hyperbolic paraboloid, which is indicated in the Eq. (6). The contour lines are hyperbolas.

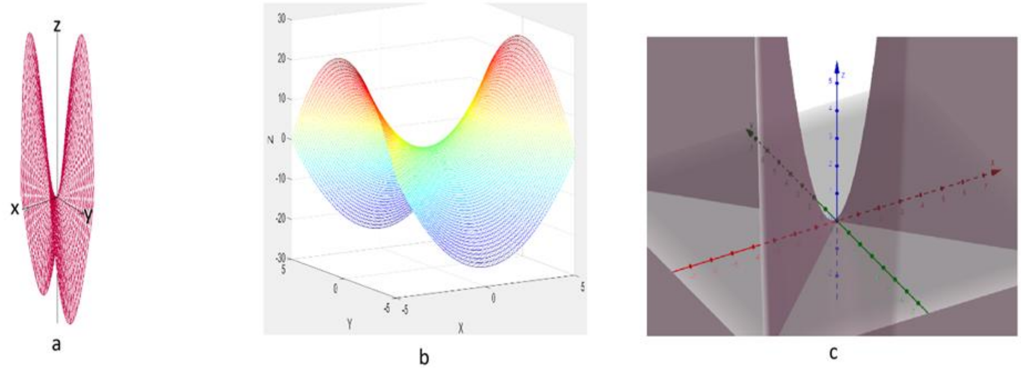

Figure 6. 3D graphic of Eq. (6) in (a) Winplot, (b) MATLAB, (c) GeoGebra

III. CONTOUR LINES OF THE EQUATIONS

Contour lines are obtained when z is equaled to different constants, so an equation of two variables is presented. For instance, in Eq. (1), if $z = 0,1,2,3,4,5$, then the correspondent equations for circumferences of different radius is presented accordingly to Eqs. (13-18).

As can be seen, the correspondent radii are. 5, $\sqrt{24}$, $\sqrt{21}$, 4, 3, and 0.

$$x^2 + y^2 = 25 \qquad (13)$$
$$x^2 + y^2 = 24 \qquad (14)$$
$$x^2 + y^2 = 21 \qquad (15)$$
$$x^2 + y^2 = 16 \qquad (16)$$
$$x^2 + y^2 = 9 \qquad (17)$$
$$x^2 + y^2 = 0 \qquad (18)$$

Contour lines for the 3D-surfaces shown in equations (1) – (6) are shown in figures 7-12 in Winplot, MATLAB and GeoGebra respectively.

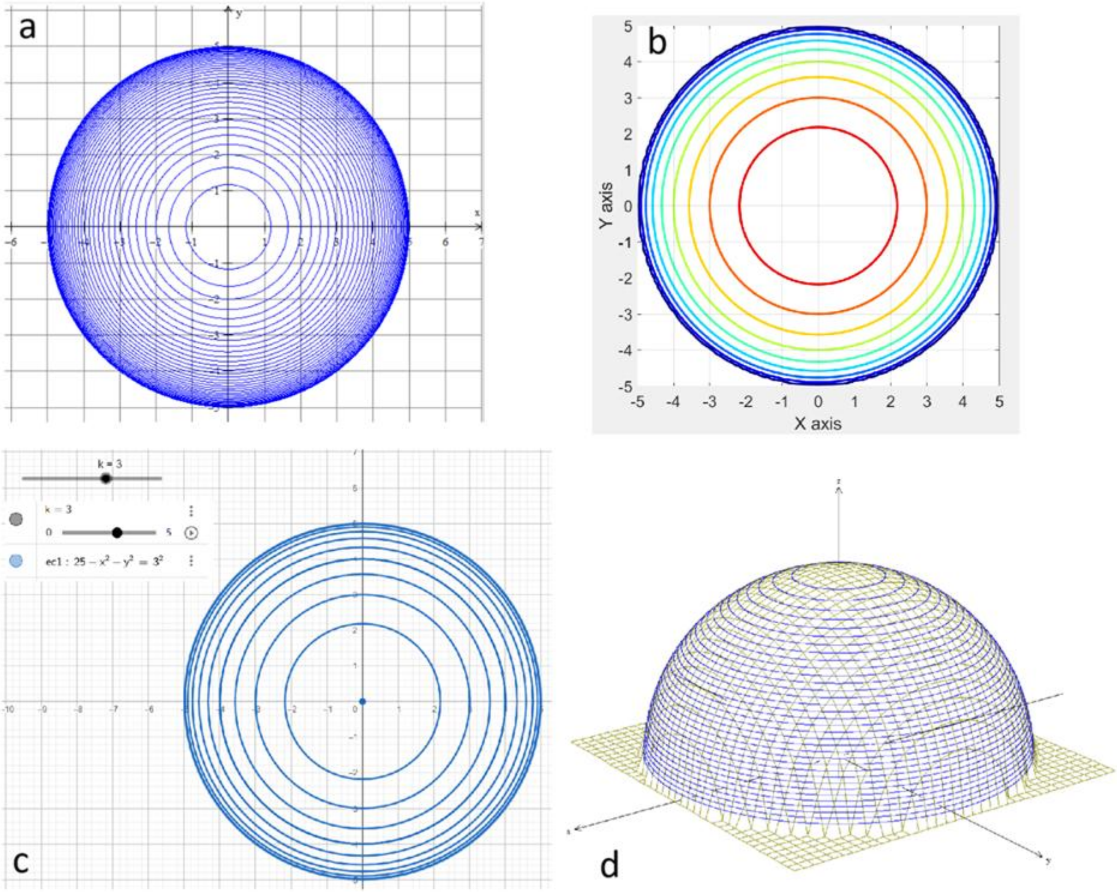

Figure 7. Contour lines derived from Eq. (1) in (a) Winplot, (b) MATLAB, (c) GeoGebra, (d) 3D perspective

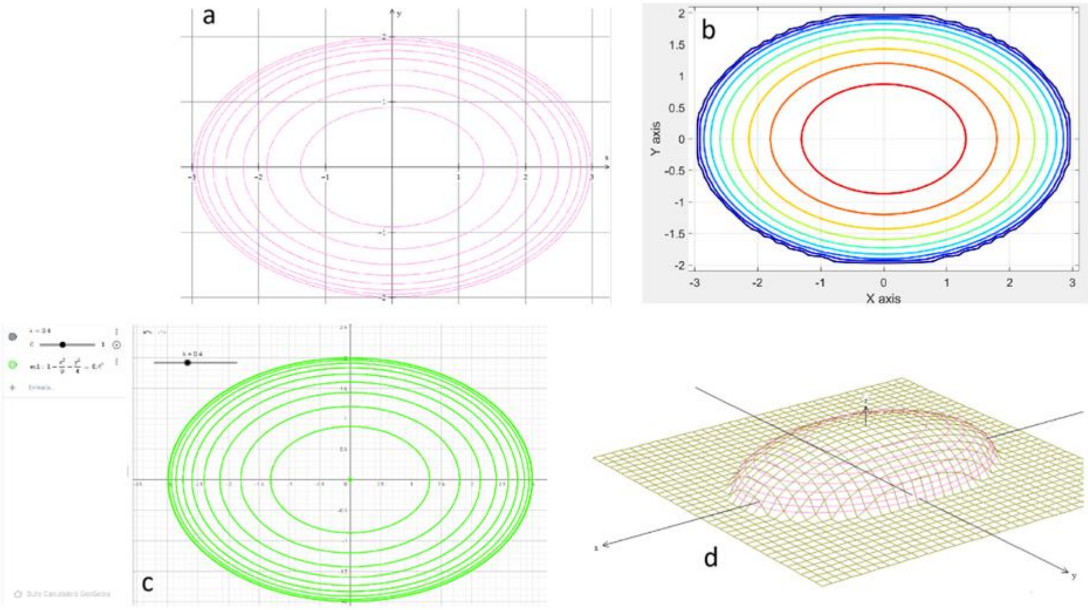

Figure 8. Contour lines derived from Eq. (2) in (a) Winplot, (b) MATLAB, (c) GeoGebra, (d) 3D perspective

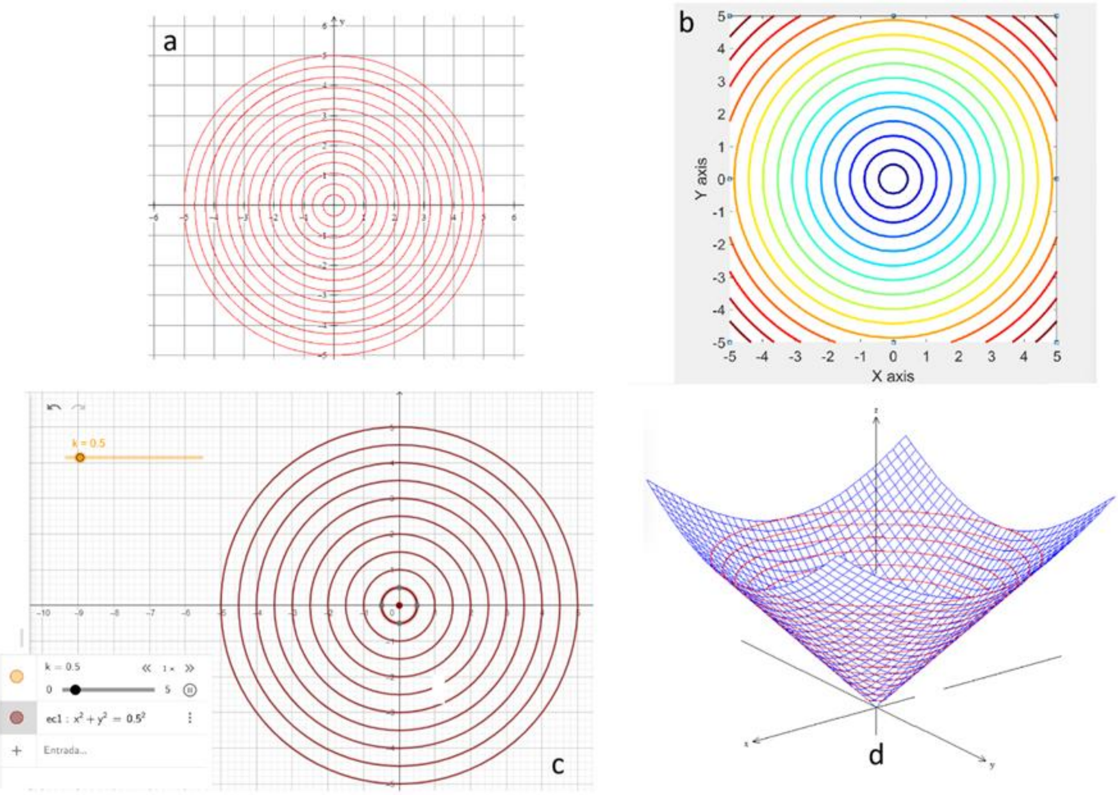

Figure 9. Contour lines derived from Eq. (3) in (a) Winplot, (b) MATLAB, (c) GeoGebra, (d) 3D perspective

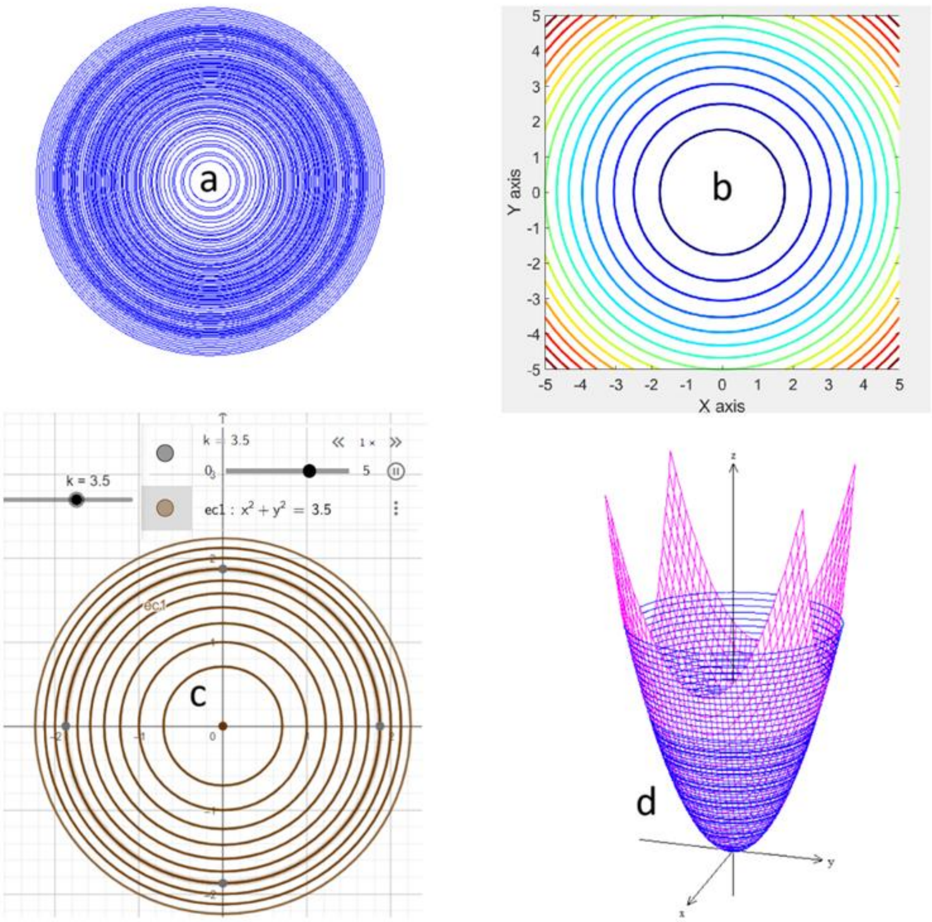

Figure 10. Contour lines derived from Eq. (4) in (a) Winplot, (b) MATLAB, (c) GeoGebra, (d) 3D perspective

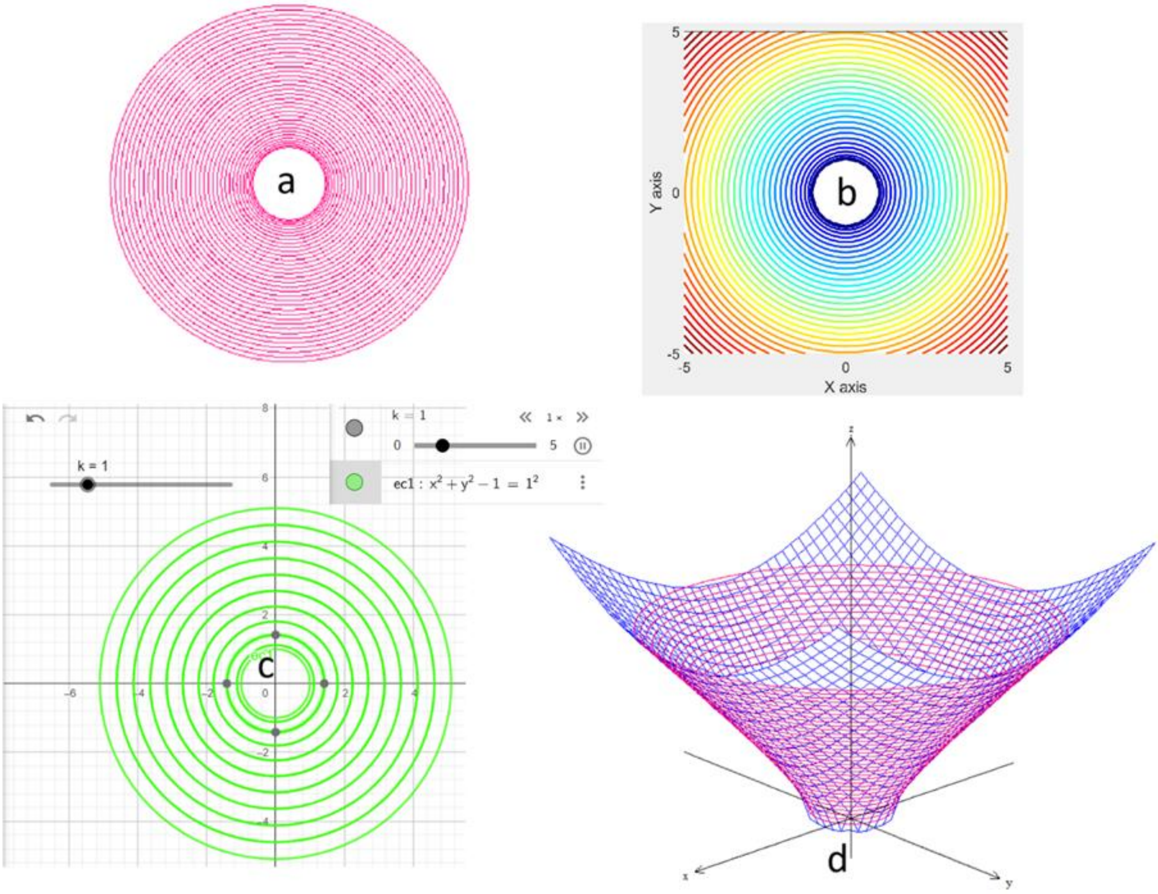

Figure 11. Contour lines derived from Eq. (5) in (a) Winplot, (b) MATLAB, (c) GeoGebra, (d) 3D perspective

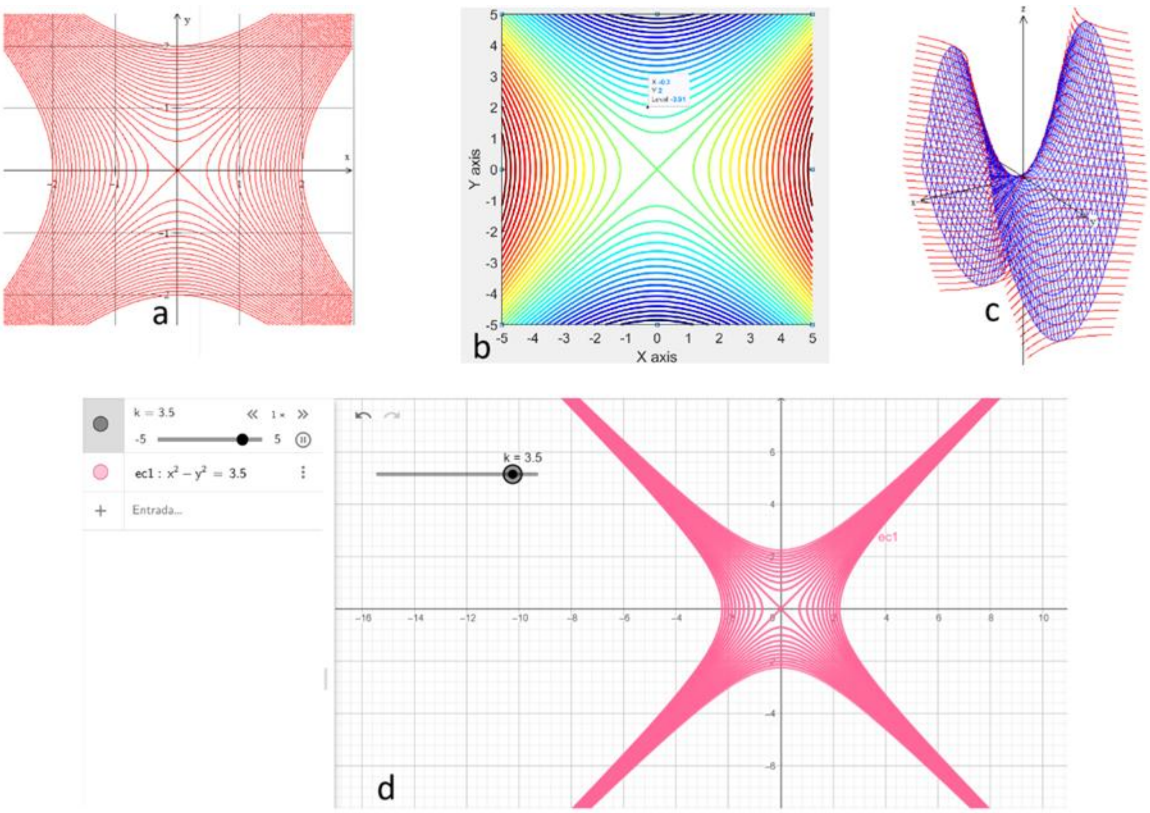

Figure 12. Contour lines derived from Eq. (6) in (a) Winplot, (b) MATLAB, (c) GeoGebra, (d) 3D perspective

IV. CONCLUSION

This work provided various software tools to generate graphs for 3D surfaces and their corresponding contour lines. This approach offered several important advantages for college students, both in terms of learning and practical skills development. First place, different software packages display surfaces and contour lines in slightly different ways. By comparing results across platforms, students strengthened their understanding of mathematical concepts instead of relying on one tool's interface since some software emphasizes symbolic computation, while others excel in numerical simulation or visualization. Students learned to approach the same problem from multiple perspectives, which trained adaptability and creativity. Surfaces and contour lines can be represented in 2D or 3D, with different color maps, resolutions, and interactive features, so exploring multiple visualization styles helped students see the math more clearly, especially for complex or abstract functions. Gaining experience in several tools during college makes students more versatile and attractive to future employers. By comparing outputs from different software, students detected inconsistencies and evaluated which representation was more accurate.

In summary, the main advantage for college students is that using different software tools to obtain surface and contour line graphs helped them build a stronger conceptual understanding, adaptability, visualization skills, and professional competence, all of which prepare them for both academic success and real-world applications.

REFERENCES

[1] Atit, K., Weisberg, S. M., Newcombe, N. S., & Shipley, T. F. (2016). Learning To Interpret Topographic Maps: Understanding Layered Spatial Information. Cognitive Research: Principles And Implications, 1(1), 2.

[2] Pick, H. L., Heinrichs, M. R., Montello, D. R., Smith, K., Sullivan, C. N., & Thompson, W. B. (2018). Topographic Map Reading. In Local Applications Of The Ecological Approach To Human-Machine Systems (Pp. 255-284). CRC Press.

[3] Wu, Q., Liu, H., Wang, S., Yu, B., Beck, R., & Hinkel, K. (2015). A Localized Contour Tree Method For Deriving Geometric And Topological Properties Of Complex Surface Depressions Based On High-Resolution Topographical Data. International Journal Of Geographical Information Science, 29(12), 2041-2060.

[4] Mostafavi, M. (2016). Cartographic Grounds: Projecting The Landscape Imaginary. Chronicle Books.

[5] Telbisz, T., Látos, T., Deák, M., Székely, B., Koma, Z., & Standovár, T. (2016). The Advantage Of Lidar Digital Terrain Models In Doline Morphometry Compared To Topographic Map Based Datasets–Aggtelek Karst (Hungary) As An Example. Acta Carsologica, 45(1).

[6] Woods, T. L., Reed, S., Hsi, S., Woods, J. A., & Woods, M. R. (2016). Pilot Study Using The Augmented Reality Sandbox To Teach Topographic Maps And Surficial Processes In Introductory Geology Labs. Journal Of Geoscience Education, 64(3), 199-214.

[7] Hsu, H. P., Tsai, B. W., & Chen, C. M. (2018). Teaching Topographic Map Skills And Geomorphology Concepts With Google Earth In A One-Computer Classroom. Journal Of Geography, 117(1), 29-39.

[8] Yeh, C. H., Lin, M. L., Chan, Y. C., Chang, K. J., & Hsieh, Y. C. (2017). Dip-Slope Mapping Of Sedimentary Terrain Using Polygon Auto-Tracing And Airborne Lidar Topographic Data. Engineering Geology, 222, 236-249.

[9] Szypuła, B. (2019). Quality Assessment Of DEM Derived From Topographic Maps For Geomorphometric Purposes. Open Geosciences, 11(1), 843-865.

[10] Seedahmed, G. (2017). A Methodology For Checking The Validity Of An Existing Contour Map Using RTK-GPS And GIS. University Of Khartoum Engineering Journal, 7(1), 1-7.

[11] Oh, J., & Lee, C. (2015). Automated Bias-Compensation Of Rational Polynomial Coefficients Of High Resolution Satellite Imagery Based On Topographic Maps. ISPRS Journal Of Photogrammetry And Remote Sensing, 100, 14-22.

[12] Newcombe, N. S., Weisberg, S. M., Atit, K., Jacovina, M. E., Ormand, C. J., & Shipley, T. F. (2015). The Lay Of The Land: Sensing And Representing Topography. Baltic International Yearbook Of Cognition, Logic And Communication, 10(1), 6.

[13] Beenakker, J. W. M., Shamonin, D. P., Webb, A. G., Luyten, G. P., & Stoel, B. C. (2015). Automated Retinal Topographic Maps Measured With Magnetic Resonance Imaging. Investigative Ophthalmology & Visual Science, 56(2), 1033-1039.

[14] Maxwell, A. E., Bester, M. S., Guillen, L. A., Ramezan, C. A., Carpinello, D. J., Fan, Y., ... & Pyron, J. L. (2020). Semantic Segmentation Deep Learning For Extracting Surface Mine Extents From Historic Topographic Maps. Remote Sensing, 12(24), 4145.

[15] Pokonieczny, K., & Borkowska, S. (2019). Using Artificial Neural Network For Labelling Polygon Features In Topographic Maps. Geoscape, 13(2).

[16] Lisle, R. J. (2020). Geological Structures And Maps: A Practical Guide. Butterworth-Heinemann.

[17] Cuevas, E., Luque, A., & Escobar, H. (2023). Graphing With MATLAB. In Computational Methods With MATLAB® (Pp. 19-56). Cham: Springer Nature Switzerland.

[18] Palafox, R. B., Moreno, M. M., Briones, J. G., Sánchez, L. E. V., & Ramírez, R. E. M. (2024). Uso De Geogebra En El Aprendizaje De Matemáticas En La Ingeniería. Ciencia Latina Revista Científica Multidisciplinar, 8(3), 2012-2027.

[19] Marinho, J. S. (2021). O Uso Do Winplot Como Software Educativo No Ensino Da Função Quadrática (Master's Thesis).

[20] Butorina, I. V., & Vasilieva, V. N. (2018, November). Surface Modeling In Autocad For Architectural And Structural Design. In IOP Conference Series: Materials Science And Engineering (Vol. 451, No. 1, P. 012125). IOP Publishing.