

Differential equations and mathematical models: An educational approach

Cristian Luis Inca Balseca¹, Franklin Marcelo Coronel Maji², Caicedo
Romero Hugo Marcelo³, Evelyn Geovanna Inca Balseca⁴, Julio
Cesar Morocho Orellana⁵, Lizeth Fernanda Silva Godoy⁶

¹Escuela Superior Politécnica de Chimborazo (ESPOCH), Facultad de
Informática y Electrónica. Tecnologías de la Información,
cristianl.inca@epoch.edu.ec

²Escuela Superior Politécnica de Chimborazo (ESPOCH),
fcoronel@epoch.edu.ec

³Universidad de las Fuerzas Armadas – ESPE, hmcaicedo@espe.edu.ec

⁴independent researcher, eve.inca1999@gmail.com

⁵Universidad Metropolitana Sede Machala, Ingeniería. Logística y
Transporte, jmoroch@umet.edu.ec

⁶independent researcher, fercha.silva1@gmail.com

Abstract

A documentary review was carried out on producing and publishing research papers on studying differential equations, mathematical models, and education. The bibliometric analysis proposed in this paper was to know the main characteristics of the volume of publications registered in the Scopus database during 2017-2021, identifying 90 publications. The information provided by the said platform was organized employing tables and figures categorizing the information by Year of Publication, Country of Origin, Area of Knowledge and Type of Publication. Once these characteristics were described, a qualitative analysis was used to refer to the position of different authors on the proposed topic. Among the main findings of this research, it is found that the United States, with 13 publications, was the country with the highest scientific production registered in the name of authors affiliated with institutions of that nation. The area of knowledge that made the greatest contribution to the construction of bibliographic material referring to the study of differential equations, mathematical models, and education was Mathematics, with 37 published documents, and the type of publication that was most used during the period mentioned above was the conference article, which represents 47% of the total scientific production.

Keywords: Differential Equations, Mathematical Models, Education.

1. Introduction

The importance of differential equations, mathematical models for both basic and social sciences, is a great challenge for teachers of mathematics and physics to find alternative methods to improve their teaching, finding pedagogical learning models that allow the motivation of students to achieve the acquisition of new skills, taking advantage of the resources available to achieve better acceptance and understanding, despite its level of complexity. In this context, Rocha (2021) states:

Higher education has faced different changes and challenges throughout its history as a product of social needs and demands, which incite in some way to adapt to the new realities of the 21st century (p. 65).

Indeed, differential equations offer several challenges, the conception of a hypothesis for the proper approach of a model, the collection of all the acquired results, and verifying, validating and comparing the possible solutions to the real data to check the efficiency of the implemented method. As can be seen, for the solution of a problem, it is necessary to propose one or several hypotheses, with which several examples must be made in order to verify, ratify, and reformulate as the case may be.

Consequently, in recent years, advances in technology, particularly in computers, have led to the teaching of mathematical sciences in courses of differential equations and mathematical models, with a methodology of experimental sciences so that the results obtained can be experimented with and checked (Hernández-Suarez et al., 2016). For this reason, this article seeks to describe the main characteristics of the compendium of publications indexed in the Scopus database related to the variables differential equations, mathematical models, and education, as well as the description of the position of certain affiliated authors during the period between 2017 and 2021.

2. General Objective

To analyze from a bibliometric and bibliographic perspective, the production of research papers on the variables Differential Equations, Mathematical Models, and Education, registered in Scopus during the period 2017-2021.

3. Methodology

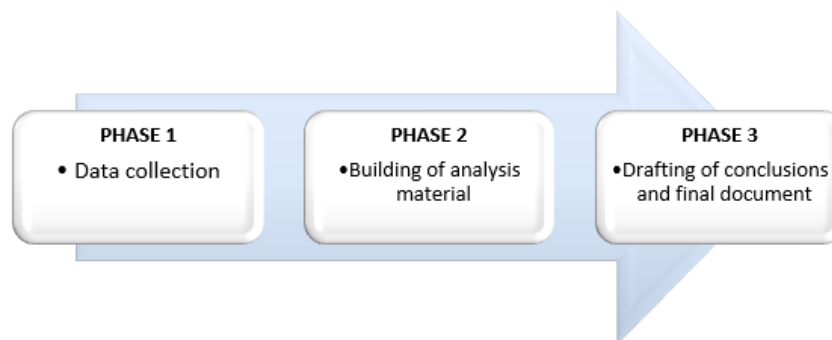
Quantitative analysis of the information provided by Scopus is performed under a bibliometric approach on the scientific production

related to the study of Differential Equations, Mathematical Models and Education. Also, from a qualitative perspective, examples of some research papers published in the area of the study mentioned above are analyzed from a bibliographic approach to describe the position of different authors on the proposed topic.

The search is performed through the tool provided by Scopus, and the parameters referenced in Figure 1 are established.

3.1 Methodological design

Figure 1. Methodological design



Source: Own elaboration

3.1.1 Phase 1: Data Collection

The data collection was carried out using the Scopus web page search tool, through which a total of 90 publications were identified. For this purpose, search filters were established consisting of:

TITLE-ABS-KEY (differential AND equations, AND mathematical AND models, AND education) AND (LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017)))

- ✓ Published papers whose variables are related to the study of Differential Equations, Mathematical Models, Education.
- ✓ Without distinction of country of origin.
- ✓ Without distinction of area of knowledge.
- ✓ Without distinction of type of publication.

3.1.2 Phase 2: Construction of analysis material

The information identified in the previous phase is organized. The classification will be made through graphs, figures and tables based on data provided by Scopus.

- ✓ Word Co-occurrence.
- ✓ Year of publication
- ✓ Country of origin of the publication.

- ✓ Knowledge area.
- ✓ Type of Publication

3.1.3 Phase 3: Drafting conclusions and final document

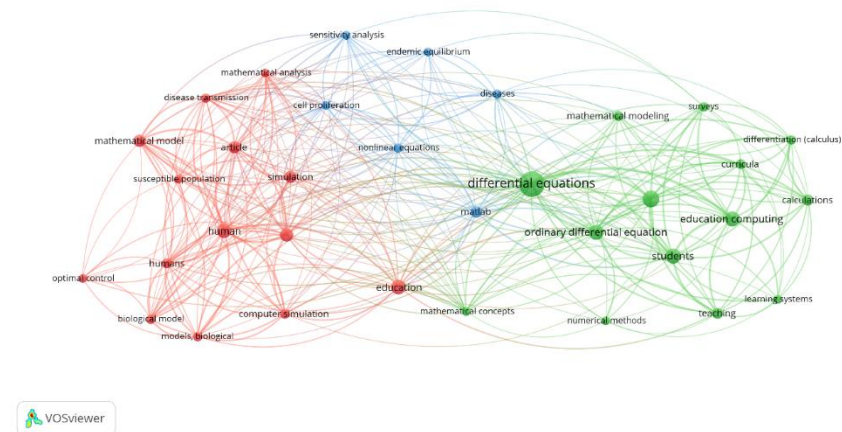
After the analysis carried out in the previous phase, the study proceeds to draft the conclusions and prepare of the final document.

4. Results

4.1 Co-occurrence of words

Figure 2 shows the co-occurrence of keywords within the publications identified in the Scopus database.

Figure 2. Co-occurrence of words



Source: Own elaboration (2022); based on data provided by Scopus.

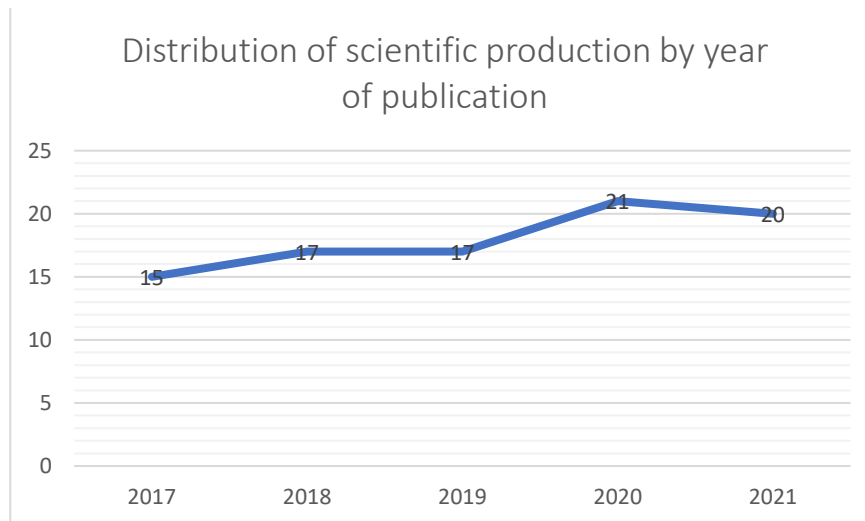
Within the study of the research reported by the Scopus platform, referring to the variables differential equations, mathematical models, and education, the object of this scientific debt is considered exposing the variable of differential equations and mathematical models as a global approach in education involves some interpretations not only in the educational field but a broad orientation of mathematical models and the various sciences that arise from this. It is for this reason that through the interpretation of Figure 2, it is possible to determine how keywords of the publications reported in Scopus, Differential Equation, Education, Integral Calculus, and Mathematical Concepts, in attention with the correlation of mathematical terminology make common denominator the didactic area of mathematics, mostly using technology since the few pedagogical strategies at the time of learning are frequent.

Moreover, with technological resources, the student makes the class more attractive, thus awakening a deep interest in the subject.

4.2 Distribution of scientific production by year of publication

Figure 3 shows how the scientific production is distributed according to the year of publication, considering the period from 2017 to 2021.

Figure 3. Distribution of scientific production by year of publication.



Source: Own elaboration (2022); based on data provided by Scopus.

The article entitled “Adoption of drone technology in mathematics education” stands out in this period (Duraj et al., 2021), whose objective was to describe a theoretical framework describing the use of drone technology in mathematics education to enhance engagement and learning with experiential learning method. In particular, that study discusses the pedagogical aspect where drones can be used in combination with various learning techniques and methods. The role of drones in mathematics education can be reflected from two aspects, the mathematical terms that make the drone work and the drone as a mathematical object and as an interceptor that can build mathematical objects. In the end, the study can be used by educators and researchers interested in drone-based mathematics learning.

4.3 Distribution of scientific production by country of origin.

Figure 4 shows the distribution of scientific production according to the nationality of the authors.

Figure 4. Distribution of scientific production by country of origin.

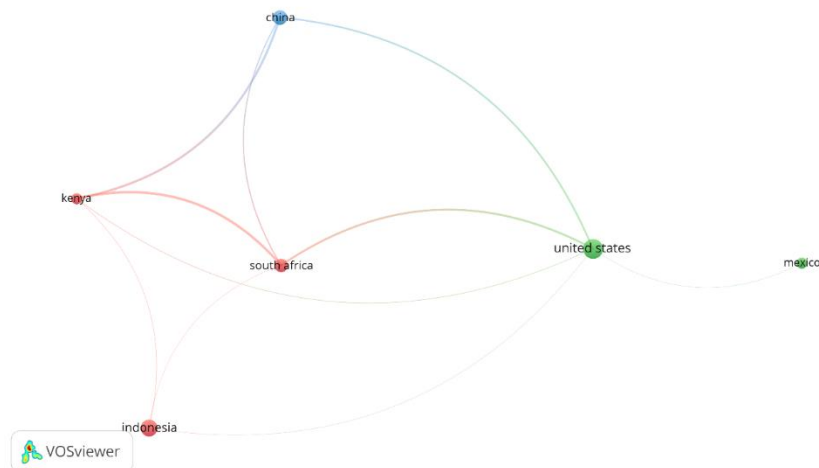


Source: Own elaboration (2022); based on data provided by Scopus.

The United States was the country with the highest number of publications registered in Scopus referring to the variable Differential equation and mathematical models, education, during the period 2017-2021 with a total of 13 publications, followed by Indonesia with 9 registrations and Porcelain with 8. Of the latter, the article entitled “MATLAB-based physics calculator: an alternative for learning means for the concept of work and energy” stands out (RA et al. Journal of Physics: Conference SeriesOpen AccessVolume 1806, Issue 131 March 2021 Article Number0120222020202020 International Conference on Mathematics and Science Education, ICMSce 2020BandungJuly 14, 2020July 15), whose objective is the development (R&D) with 4Dmodel development (Definition, Design, Development and Dissemination). The Matlab-based physics calculator is created using Matlab software through a multimedia development format that formulates, simulates and theorizes. The above research helps future generations further learn and understand their work in a simulated formula.

At this point, it should be noted that the production of scientific publications, when classified by country of origin, presents a special characteristic and that is the collaboration between authors with different affiliations to public and private institutions, and these institutions can be from the same country or different nationalities so that the production of an article co-authored by different authors from different countries of origin allows each of the countries to add up as a unit in the overall publications. This is best explained in Figure 5, which shows collaborative workflow from different countries.

Figure 5. Co-citations between countries.



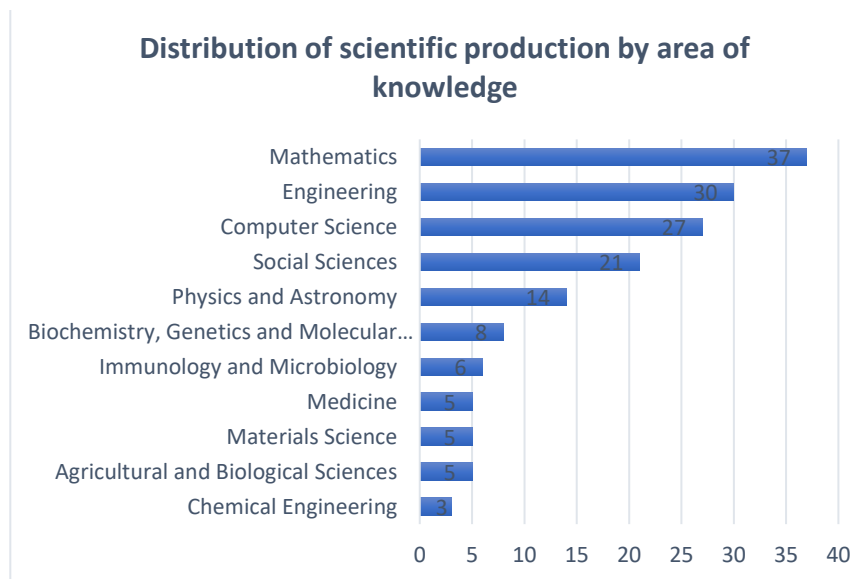
Source: Own elaboration (2022); based on data provided by Scopus.

Figure 5 shows how research is grouped according to international participation among affiliated authors. Outstanding participation is evident among authors affiliated with institutions in the United States, China and Kenya, South Africa, with authors from Kenya and collaboration with researchers from the United States and China.

4.4 Distribution of scientific production by area of knowledge

Figure 5 shows how the production of scientific publications is distributed according to the area of knowledge through which the different research methodologies are executed.

Figure 6. Distribution of scientific production by area of knowledge.



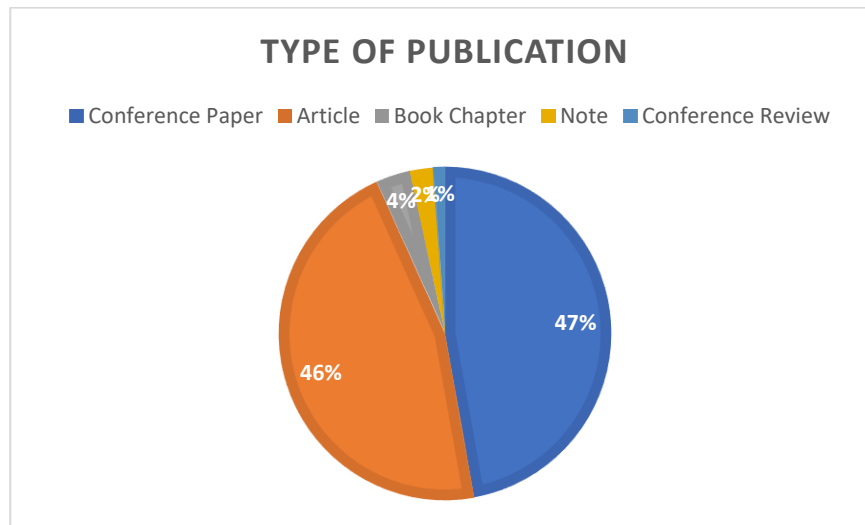
Source: Own elaboration (2022); based on data provided by Scopus.

Mathematics was the knowledge area with the highest number of publications registered in Scopus, with 37 papers that have based their methodologies on the variables Differential equations and mathematical models, education. In second place, Engineering with 30 documents. The above can be explained thanks to the study to improve academic performance in mathematical skills in undergraduate education. The impact analysis in higher education is reflected in an article registered in the area of Engineering entitled “Mathematical content of an undergraduate course on deep learning” (Shiberu, ASEE Annual Conference and Exhibition, Conference Proceedings Volume 2020-June22 June 2020 Article number10012020 ASEE Virtual Annual Conference, ASEE 2020Virtual, online22 June 2020to26 June 2020Code164392), in which the author explains the empirical models which are based on solving challenging problems, such as autonomous driving in unstructured environments or allowing robots to grasp arbitrary objects. With the invention and widespread use of computers, the applied mathematics curriculum has evolved to include courses such as numerical analysis that complement analytical modeling with simulation and numerical solutions to complex problems. Even introductory STEM courses such as calculus, differential equations, matrix algebra, and statistics turn to simulation and computer-based solutions.

4.5 Type of publication

Figure 7 shows how the bibliographic production is distributed according to the author’s chosen publication type.

Figure 7. Type of publication



Source: Own elaboration (2022); based on data provided by Scopus.

The most frequently used type of publication by researchers was the Section Paper Article; 47% of the total scientific output corresponds to this document. In second place, articles with 46% and Book Chapters with 4%. In this last category, emphasis is placed on the article entitled “Analysis of the Educational Process System” (Ganicheva & Ganichev, Proceedings of the CEUR WorkshopVolume 3057, pages 161 - 1662021 6th International Scientific and Practical Conference "Distance Learning Technologies", DLT 2021Yalta, Crimea20 September 2021to22 September 2021Code175606). Its objective is the application of Markovian chains to analyze the educational process system. The structural scheme of the educational process is developed and the processes of the educational system are described using discrete and continuous Markovian chains and network modeling, a method for analyzing the stability of the Kolmogorov system of equations that corresponds to the considered model of the educational process.

5. Conclusions

Through the bibliometric analysis carried out in this research work, it was possible to establish that the United States was the country with the most significant number of published records on the variable of differential equations, mathematical models, and education, with a total of 13 publications in the Scopus database during the period 2017-2021. Similarly, it was possible to establish that applying theories framed in the area of Mathematical Sciences was the most frequently used in measuring the impact of differential equations and mathematical models based on education. It is important to emphasize that most of the authors help with the strengthening of new pedagogical ideas, the

use of technological resources for the elaboration of new additional strategies to achieve, on the one hand, to motivate the student for experimentation, elaboration and simulation of interactive tools. Likewise, it is necessary to motivate methodological strategies related to applying differential equations to contribute to new learning and teaching processes at the undergraduate level. However, it can be concluded that research related to the study of the variables of differential equations, mathematical models, and education has strengthened the creation of new educational practices through the use of all the potential offered by technological tools, so it is expected that by identifying the main features in the total scientific production reported in Scopus, the scientific community is encouraged to intensify efforts in the search for the generation of new knowledge around these variables and thus achieve greater theoretical and pedagogical support at different educational levels.

Bibliography

- Duraj, S., Pepkolaj, L., & Hoxha, G. (2021). Adopting Drone Technology in Mathematical Education. HORA 2021 - 3rd International Congress on Human-Computer Interaction, Optimization and Robotic Applications, Proceedings11 June 2021 3rd International Congress on Human-Computer Interaction, Optimization and Robotic Applications, HORA 2021Ankara11 June 20.
- Golinko, I., & Galytska, I. (2021). Mathematical modeling of dynamic heat-mass exchange processes for a spray-type humidifier doi:10.1007/978-3-030-55506-1_6 Retrieved from www.scopus.com
- Gutiérrez, J. A., & Gallegos, R. R. (2019). Theoretical and methodological proposal on the development of critical thinking through mathematical modeling in the training of engineers. Paper presented at the ACM International Conference Proceeding Series, 941-948. doi:10.1145/3362789.3362828 Retrieved from www.scopus.com
- Han, S., Lim, B., Lee, H., & Bae, S. H. (2018). Development of a user-friendly training software for pharmacokinetic concepts and models. *Translational and Clinical Pharmacology*, 26(4), 166-171. doi:10.12793/tcp.2018.26.4.166
- Hu, F. (2021). Bidirectional promotion of ideological and political education in curriculum and online teaching-taking online teaching of mathematics as an example. Paper presented at the ACM International Conference Proceeding Series, 916-918. doi:10.1145/3456887.3457104 Retrieved from www.scopus.com
- Jiménez, F. R. L., Ruge, I. A. R., & Jiménez, A. F. L. (2020). Modeling and control of a two wheeled auto-balancing robot: A didactic platform for control engineering education. Paper presented at the Proceedings of the LACCEI International Multi-Conference for Engineering, Education and Technology, doi:10.18687/LACCEI2020.1.1.556 Retrieved from www.scopus.com
- Kassa, S. M., & Workineh, Y. H. (2018). Effect of negligence and length of time delay in spontaneous behavioural changes for the response to epidemics.

- Mathematical Methods in the Applied Sciences, 41(18), 8613-8635. doi:10.1002/mma.4926
- Kawamura, M. L., Alleyne, A. G., & Sutanto, E. (2017). An educational laboratory experimental system for teaching chemical reaction process dynamics and control. Paper presented at the ASEE Annual Conference and Exposition, Conference Proceedings, , 2017-June Retrieved from www.scopus.com
- Kaymakamzade, B., Şanlıdağ, T., Hınçal, E., Sayan, M., Sa'ad, F. T., & Baba, I. A. (2018). Role of awareness in controlling HIV/AIDS: A mathematical model. Quality and Quantity, 52, 625-637. doi:10.1007/s11135-017-0640-2
- Kerr, R., Thomson, W. M., & Smith, D. J. (2019). Mathematical modelling of the vitamin C clock reaction. Royal Society Open Science, 6(4) doi:10.1098/rsos.181367
- Khavinson, M. Y., & Kulakov, M. P. (2017). Gravitational model of population dynamics. Bulletin of the South Ural State University, Series: Mathematical Modelling, Programming and Computer Software, 10(3), 80-93. doi:10.14529/mmp170307
- Kinoshita, F., & Takada, H. (2017). Numerical simulation of equilibrium systems while viewing stereoscopic video clips. Paper presented at the ICCSE 2017 - 12th International Conference on Computer Science and Education, 73-76. doi:10.1109/ICCSE.2017.8085466 Retrieved from www.scopus.com
- Kouilily, F., Aboulkhouatem, F. Z., Yousfi, N., Achtaich, N., & El Khasmi, M. (2018). Modeling the social and epidemiological causes of hearing loss. Revista Mexicana De Ingenieria Biomedica, 39(3), 238-248. doi:10.17488/RMIB.39.3.3
- Kráčalik, M. (2020). Mathematical modelling of continuum mechanics in context of industry 4.0 with emphasis on mathematical education. Paper presented at the 19th Conference on Applied Mathematics, APLIMAT 2020 Proceedings, 712-718. Retrieved from www.scopus.com
- Kurniawan, F., Nugroho, S. M., & Hariadi, M. (2018). Smart city priority correlation using differential equation. Computing in Science and Engineering, doi:10.1109/MCSE.2018.2873936
- Lambura, A. G., Mwanga, G. G., Luboobi, L., & Kuznetsov, D. (2020). Mathematical model for optimal control of soil-transmitted helminth infection. Computational and Mathematical Methods in Medicine, 2020 doi:10.1155/2020/6721919
- Ledder, G. (2017). Scaling for dynamical systems in biology. Bulletin of Mathematical Biology, 79(11), 2747-2772. doi:10.1007/s11538-017-0339-5
- Levy, B., Edholm, C., Gaoe, O., Kaondera-Shava, R., Kgosimore, M., Lenhart, S., . . . Nyabadza, F. (2017). Modeling the role of public health education in ebola virus disease outbreaks in sudan. Infectious Disease Modelling, 2(3), 323-340. doi:10.1016/j.idm.2017.06.004
- Li, X., & Huang, Z. J. (2017). An inverted classroom approach to educate MATLAB in chemical process control. Education for Chemical Engineers, 19, 1-12. doi:10.1016/j.ece.2016.08.001
- Liu, X. -, & He, D. -. (2020). Research on of competitive nonlinear dynamic information diffusion modeling in online social network. [在线社交网络的竞争性非线性动力学信息传播模型研究] Jisuanji Xuebao/Chinese Journal of Computers, 43(10), 1842-1861. doi:10.11897/SP.J.1016.2020.01842

- Ma, W., Jin, M., Liu, Y., & Xu, X. (2019). Empirical analysis of fractional differential equations model for relationship between enterprise management and financial performance. *Chaos, Solitons and Fractals*, 125, 17-23. doi:10.1016/j.chaos.2019.05.009
- Makarenko, O., & Samorodov, Y. (2021). To the statement of tasks of research of migration processes in education and science. Paper presented at the CEUR Workshop Proceedings, , 3126 222-227. Retrieved from www.scopus.com
- Malakhov, A. A., & Fashchevskiy, N. N. (2019). MATLAB and SIMULINK educational potentiality in analysis of dynamic systems. Paper presented at the AIP Conference Proceedings, , 2195 doi:10.1063/1.5140169 Retrieved from www.scopus.com
- Momoh, A. A., Abdullahi, H. M., Abimbola, N. G. A., & Michael, A. I. (2021). Modeling, optimal control of intervention strategies and cost effectiveness analysis for buruli ulcer model. *Alexandria Engineering Journal*, 60(2), 2245-2264. doi:10.1016/j.aej.2020.12.042
- Mushanyu, J., & Nyabadza, F. (2018). A risk-structured model for understanding the spread of drug abuse. *International Journal of Applied and Computational Mathematics*, 4(2) doi:10.1007/s40819-018-0495-9
- Narendranath, A. D. (2017). Introducing the galerkin method of weighted residuals into an undergraduate elective course in finite element methods. Paper presented at the ASEE Annual Conference and Exposition, Conference Proceedings, , 2017-June Retrieved from www.scopus.com
- Nur, W., Trisilowati, Suryanto, A., & Kusumawinahyu, W. M. (2021). Mathematical model of schistosomiasis with health education and molluscicide intervention. Paper presented at the Journal of Physics: Conference Series, , 1821(1) doi:10.1088/1742-6596/1821/1/012033 Retrieved from www.scopus.com
- Nyang'inja, R. A., Angwenyi, D. N., Musyoka, C. M., & Orwa, T. O. (2018). Mathematical modeling of the effects of public health education on tungiasis—a neglected disease with many challenges in endemic communities. *Advances in Difference Equations*, 2018(1) doi:10.1186/s13662-018-1875-5
- Orfali, F., Vieira, F. P. B., & El Hage, F. S. (2018). A curricular innovation in the teaching of calculus in engineering programs. Paper presented at the International Symposium on Project Approaches in Engineering Education, , 8 232-239. Retrieved from www.scopus.com
- Osman, S., Makinde, O. D., & Theuri, D. M. (2020). Mathematical modelling of listeriosis epidemics in animal and human population with optimal control. *Tamkang Journal of Mathematics*, 51(4), 261-287. doi:10.5556/J.TKJM.51.2020.2860
- Ostadzad, M. H., Baroumand, S., & Mahmoudi, M. R. (2020). Optimization of public health education parameters for controlling the spread of HIV/AIDS infection. *Symmetry*, 12(4) doi:10.3390/SYM12040659
- Ostadzad, M. H., Shahmorad, S., & Erjaee, G. H. (2020). Study of public health education effect on spread of HIV infection in a density-dependent transmission model. *Differential Equations and Dynamical Systems*, 28(1), 201-215. doi:10.1007/s12591-016-0310-1

- Ponjavic, M. M., & Šekara, T. B. (2020). Singularity excitations and initial value problem in continuous LTI systems. *IEEE Access*, 8, 176750-176757. doi:10.1109/ACCESS.2020.3023334
- Pratama, R. A., Ruslau, M. F. V., & Nurhayati. (2021). Global analysis of stage structure two predators two prey systems under harvesting effect for mature predators. Paper presented at the *Journal of Physics: Conference Series*, 1899(1) doi:10.1088/1742-6596/1899/1/012099 Retrieved from www.scopus.com
- Raczynski, S. (2018). Influence of the gregarious instinct and individuals' behavior patterns on macro migrations: Simulation experiments. *Journal of Human Behavior in the Social Environment*, 28(2), 204-220. doi:10.1080/10911359.2017.1388758
- Rhodes, A., & Hillen, T. (2019). A mathematical model for the immune-mediated theory of metastasis. *Journal of Theoretical Biology*, 482 doi:10.1016/j.jtbi.2019.109999
- Rivera-Figueroa, A., & Lima-Zempoalteca, I. (2021). Motion of a simple pendulum: A digital technology approach. *International Journal of Mathematical Education in Science and Technology*, 52(4), 550-564. doi:10.1080/0020739X.2019.1692934
- Rodriguez-Gallegos, R. (2019). Modeling complex problems in the teaching of mathematics. Paper presented at the *Proceedings - IEEE 10th International Conference on Technology for Education, T4E 2019*, 122-125. doi:10.1109/T4E.2019.00-38 Retrieved from www.scopus.com