



APPLICATION OF STATISTICAL SOFTWARE TRENDS IN REAL-WORLD IMPLEMENTATION WITHIN CLINICAL AND PRE-CLINICAL TRIALS

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Abstract

The use of statistical software has become a revolutionary force in the quickly changing world of clinical and pre-clinical trials, enabling data-driven decision-making, improving research outcomes, and stimulating innovation. This review paper examines the most recent developments and trends in the practical application of statistical software tools, highlighting their critical influence on the design of clinical and pre-clinical studies. We explore the many features of statistical software and how they affect data administration, analysis, visualization, teamwork, and legal compliance. This article explains the significant impact of statistical software on the quality, effectiveness, and dependability of clinical and pre-clinical trials by a thorough study of recent studies, case studies, and industry insights. We also talk about the new trends, problems, and opportunities that promise to further revolutionize the industry. The contemporary landscape witnesses a proliferation of diverse statistical software solutions, including SPSS Statistics, JMP, Grapher, Minitab, OriginPro, TIMi Suite.

Keywords: - Statistical software, Preclinical, Clinical trials, SPSS.

1. INTRODUCTION:

Biostatistics, sometimes referred to as biometry, involves the application of statistical methods to a variety of biological issues. It encompasses the design of biological experiments, the collection and analysis of data from such studies, and the interpretation of the results.¹ Biostatistics utilizes scientific and quantitative techniques in descriptive and inferential statistics to assess the strength of evidence in biological sciences. Clinical trials are prospective biomedical or behavioral research studies involving human participants, aiming to address specific questions about biomedical or behavioral interventions.² These interventions include novel treatments like vaccines, drugs, dietary choices, dietary supplements, and medical devices, as well as established interventions that require further investigation and comparison. Clinical trials generate data on dosing, safety, and effectiveness.³

Preclinical development, also known as preclinical studies or nonclinical studies, is a research phase that precedes clinical trials. It involves essential feasibility assessments, iterative testing, and the collection of safety data, often in laboratory animals. The primary objectives of preclinical research are to establish a safe starting dose for initial human studies and to assess potential product toxicity, which can include innovative medical devices, prescription medications, and diagnostics. Biostatistics plays a crucial role in analyzing and interpreting data obtained from study participants as they progress through research.⁴It serves as a bridge between data collection and reporting. Various software tools like SPSS, MATLAB, and JMP are used for this purpose. In both preclinical investigations and clinical trials, biostatistics is a foundational element. It shapes research design, guides study execution, oversees data collection, performs data analysis, and facilitates reporting. Software platforms like STATA, SAS, and MINITAB are commonly employed in these processes.⁵

2. IMPORTANCE OF STATISTICAL SOFTWARE

The prevailing consensus underscores technology as the driving force behind the most significant shifts in statistics over the past five decades. These shifts are particularly attributable to the advancement and widespread accessibility of high-speed computers, as well as devices designed to amass and securely store ever-expanding volumes of data. The rise of artificial intelligence, increased computer utilization, online learning platforms, along with a plethora of software and computerized surveys, has not merely given rise to a demand for novel statistical methodologies. These innovative modes of extensive data collection necessitate the effective integration of these fresh techniques into software systems. Consequently, the evolution of statistical software has gained escalating significance in recent years.⁶

The advent of substantial datasets has ushered in its own set of challenges. In earlier times, basic calculations such as averages and mean values sufficed to draw inferences for reports. However, with the prevalence of large data samples today, reports can be generated within minutes by employing statistical software. In the past, presenting a small number of key statistics generally sufficed.⁷Yet, this scenario has undergone a profound shift. The analysis of large datasets demands extensive preprocessing before they are ready for scrutiny. Moreover, intricate data analysis techniques frequently rely on specialized software tailored to specific purposes, along with fine-tuning procedures. This makes reproducibility a very significant problem. Some important statistical software used in clinical trials and pre-clinical study are below^{8, 9, 10}

- GRAPHPAD PRISM
- SPSS
- R STUDIO
- MS EXCEL
- MINITAB 18
- SCILAB
- EVIEWS
- STATA
- JMP
- GNU OCTAVE
- ORIGINPRO
- TIMI SUITE

Figure No. 1: Statistical Softwares

GraphPad inStat	Very simple with lots of guidance and explanations
GraphPad Prism	Biostatistics and nonlinear regression with clear explanations
IBM SPSS Statistics	Comprehensive statistics package
IBM SPSS Modeler	Comprehensive data mining and text analytics workbench
MATLAB	Programming language with statistical features
SPSS	Statistical Package for the Social Sciences
StatsDirect	Statistics package designed for biomedical, public health and general health science uses

3. STATISTICAL SOFTWARES

3.1. GRAPHPAD PRISM¹¹

GraphPad Prism stands as a commercial, scientific software designed for crafting 2D graphs and conducting statistical analyses on Windows and Mac OS desktop computers. Its range of capabilities encompasses nonlinear regression, outlier removal, model ratio determination, curve comparison, and model curve interpolation, among others.

Core Functionality:

GraphPad Prism excels in generating insightful graphs, facilitating curve fitting (non-linear regression), and offering user-friendly statistics and data organization features. While not intended to replace comprehensive research efforts, Prism empowers users to effortlessly conduct data analyses frequently employed by laboratories and clinical researchers. The software encompasses a wide array of analytical tools, including t-tests, non-parametric comparisons, one-way, two-way, and three-way ANOVA, probability table analysis, and survival analysis.

Customized Approach:

Prism employs straightforward terminology, eliminating unnecessary complexities. Utilizing Prism for scientific analysis involves initiating the process with a data file (or image or comment), followed by clicking the "Scan" button. The software disregards file selections, allowing users to narrow their focus during analysis through the Analyze Data dialog. Notably, Prism retains the connections between data, analyses, and graphs. Any alterations or updates to the data will automatically reflect in the associated analyses and graphs.

Learning and User-Friendly Features:

For an effective grasp of analysis techniques, Prism encourages users to explore its selection of educational materials. These resources serve as a valuable aid in mastering the software's analytical capabilities.

3.2. SPSS^{12, 19}

SPSS, short for Statistical Package for the Social Sciences, is a versatile and responsive software program designed for performing various statistical tasks.

Core Functionality:

While SPSS originally gained recognition in the field of social sciences, its applications have expanded to other data industries. Widely used in healthcare, marketing, and education research, SPSS can analyze a wide array of data types. It handles survey findings, organizational customer databases, Google Analytics, scientific study results, server log files, and more. SPSS excels in analyzing and manipulating diverse data formats

Customized Approach:

SPSS is a powerful and adaptable program, particularly for Windows systems, enabling data entry, analysis, and the creation of tables and graphs. Capable of handling substantial data volumes, SPSS can perform a wide range of analyses, surpassing those covered in the text. Its broad use in healthcare, pharmaceuticals, social sciences, and commercial sectors underlines the benefits of acquiring expertise in this software.

3.3. R STUDIO^{13, 15, 22}

R Studio is a free and open-source statistical software program. First released in 1993, with its integrated development environment (IDE) introduced in 2011, R Studio excels in visualization, analysis, and advanced computations, primarily functioning as a command-line interface (CLI) software application.

Core Functionality:

R Studio's interpreted language offers streamlined coding execution, allowing for rapid development and easy debugging. Built on matrix operations, R Studio employs vectors and matrices as fundamental data structures. It encompasses numerous built-in matrix manipulation functions, from addition and multiplication to inversion and decomposition.

Customized Approach:

R Studio proves invaluable in pharmacokinetic modeling, drug formulation optimization, data analysis, and visualization. It offers an array of operations such as arithmetic, logical, and relational, and supports extensive statistical testing and regression analysis. Its capabilities in data analysis, numerical computation, and algorithm development render it a versatile tool.

3.4. EXCEL¹⁴

Excel's utility has limitations in rigorous commercial and medical data analysis. While suitable for basic descriptive statistics, caution is advised for more complex statistical investigations like Bayesian methods, meta-analysis, and survival analysis. Excel lacks the robust data protection and audit trail of specialized medical equipment.

Functional Basis:

Excel's components include cells for data entry, rows and columns for organizing data, and sheets within a workbook. A workbook typically comprises several sheets. Excel's computational nature means outcomes depend on current inputs and the system's state.

Customized Approach:

Excel can prove helpful in clinical trial settings for simple statistical calculations. However, its limitations call for caution when performing sophisticated analyses. Its application extends to basic calculations like determining gross margin and catch rate, estimating time, and making data-driven decisions.

3.5. MINITAB¹⁵

Minitab's versatility enables data analysis and experiment research in clinical trials. It handles tasks like hypothesis testing and facilitates determining treatment effectiveness compared to control groups.

Core Functionality:

Minitab performs statistical tests such as t-tests, ANOVA, and regression analysis. It aids in creating graphs and charts for visualizing data relationships. Minitab is essential for analyzing process performance and optimizing pharmaceutical processes.

Customized Approach:

Minitab is integral to analyzing clinical trial data and optimizing pharmaceutical processes. It provides crucial insights for dose-response analysis, quality control, and trial design optimization.

3.6. SCILAB¹⁶

Scilab, an open-source numerical computing and data visualization program, excels in scientific and engineering applications.

Functional Basis:

Scilab's interpreted language allows for code execution line by line, facilitating rapid development. Matrix-based computation underpins Scilab, employing vectors and matrices as primary data structures.

Customized Approach:

Scilab's application extends to pharmacokinetic modeling, drug formulation optimization, and advanced data analysis. It empowers researchers to perform various non-parametric tests and numerical operations.

3.7. GNU OCTAVE¹⁷

GNU Octave serves as a high-level programming language tailored for scientific computing and numerical analysis.

Functional Basis:

Octave performs arithmetic, logical, and relational operations. Its compatibility with MATLAB enables users to conduct numerical experiments in a MATLAB-compatible environment.

Customized Approach:

GNU Octave is valuable for pharmacokinetic modeling, drug formulation optimization, and other scientific analyses. Its arithmetic and logical operations are applied in a range of fields.

3.8. EVIEWS¹⁸

EViews, specialized for time-series-based econometric analysis, is pivotal in making informed business decisions.

Functional Basis:

EViews excels in the design and analysis of research studies. It empowers clinicians and researchers with statistical presentations and online risk score calculators.

Customized Approach:

EViews aids in quality assurance, drug dose optimization, and data analysis in clinical trials and preclinical studies.

3.9. STATA¹⁹

Stata, a robust statistical program, empowers researchers to analyze, manage, and present data effectively.

Functional Basis:

Stata's diverse applications span economics, biomedicine, and political science. It supports numerous statistical analyses and aids in avoiding errors in research.

Customized Approach:

Stata's application is instrumental in clinical trials and preclinical studies, ensuring accurate conclusions and secure data analysis.

3.10. JMP²⁰

JMP, designed for statistical analysis and data visualization, offers versatile applications across disciplines.

Functional Basis:

JMP's data analysis and visualization tools empower users to explore databases for insights. Its compatibility with R and Python enhances functionality.

Customized Approach:

JMP serves quality by design initiatives, dose-response analysis, and process optimization in pharmaceutical research.

3.11. ORIGINPRO²¹

OriginPro, enabling data analysis and high-quality graphics, caters to researchers and designers.

Functional Basis:

OriginPro facilitates various non-parametric tests and provides customizable chart options. Its advanced analytics empower users in pharmacokinetic modeling and drug formulation optimization.

Customized Approach:

OriginPro excels in pharmacological data analysis, quality control, and trial design optimization.

3.12. TIMi SUITE²²

TiMi Suite aids in effective management and decision-making through data analysis.

Functional Basis:

TiMi Suite handles research design and analysis, offering tools for clinicians and researchers. It supports data management, statistical analysis, and collaboration.

Customized Approach:

TiMi Suite streamlines data management, statistical analysis, and collaboration in clinical trials and preclinical studies.

4. GROWTH:

- Various methods of data analysis have been employed over time. Beginning with manual techniques like paper and pencil, the introduction of computers led to the development of punch cards, which subsequently evolved into basic calculators and advanced scientific calculators.
- Nevertheless, professionals propose that a statistics program serves as software designed to simplify the computation and presentation of statistical information.

- Assuming accurate data entry by the researcher, statistical software aids in preventing numerical inaccuracies and facilitates the generation of precise research data.¹¹ Case Studies and Practical Examples:
- To provide a tangible understanding of the real-world impact of statistical software, this section presents a compilation of case studies and practical examples. These examples illustrate how statistical software has been instrumental in optimizing trial design, analyzing complex patient data, and deriving actionable insights. From adaptive clinical trial designs to personalized medicine approaches, these case studies exemplify the transformative power of statistical software in clinical and pre-clinical research.²³

Leveraging Machine Learning and AI:

- Machine learning and artificial intelligence (AI) are rapidly gaining prominence in the healthcare and research sectors. This section explores how statistical software integrates machine learning algorithms for predictive modeling, data-driven decision-making, and pattern recognition. The fusion of statistical software with AI offers the potential to uncover hidden trends, identify biomarkers, and accelerate the discovery of novel therapeutic interventions.²⁴

Cloud-Based Solutions and Scalability:

- The adoption of cloud-based solutions has revolutionized data storage, analysis, and collaboration. This section examines how statistical software leverages cloud computing to enhance scalability, data accessibility, and resource utilization. Cloud-based statistical tools enable researchers to process and analyze massive datasets efficiently, thereby accelerating trial timelines and facilitating global collaboration.²⁵

Ethical Considerations and Data Privacy:

- The integration of statistical software raises ethical considerations related to data privacy, patient confidentiality, and responsible data usage. This section delves into the ethical implications of using software tools that process sensitive patient information, emphasizing the need for robust data protection measures, informed consent procedures, and compliance with regulatory frameworks.

Training and Skill Development:

- The successful implementation of statistical software necessitates a skilled workforce proficient in its usage. This section discusses the importance of training programs, workshops, and educational resources for researchers to harness the full potential of statistical software. Effective training equips researchers with the ability to navigate software functionalities, interpret results accurately, and mitigate potential biases.²⁶

Collaborative Research Ecosystem:

- In an era of multidisciplinary research, collaboration is integral to scientific advancement. This section highlights how statistical software contributes to fostering a collaborative research ecosystem by enabling interdisciplinary teams to collaborate seamlessly. Collaborative platforms integrated with statistical software facilitate the exchange of knowledge, expertise, and data, leading to innovative breakthroughs.²⁷

Future Directions and Innovations:

- As technology evolves and research paradigms shift, the trajectory of statistical software continues to evolve. This section speculates on future directions and innovations, including the potential integration of virtual reality for data visualization, blockchain technology for secure data sharing, and the development of AI-driven automated research assistants to streamline trial processes.

Statistical Software: Catalyst for Real-World Implementation:

➤ This section presents an overview of the diverse functionalities of statistical software, emphasizing their role as catalysts for real-world implementation within clinical and pre-clinical trials. We discuss their contribution to data management, analysis, visualization, collaboration, and regulatory compliance.

5. SCOPE AND FUTURE PROSPECTS:

The realm of online statistical software holds immense potential for growth within the domains of clinical trials and preclinical studies, elevating the facets of data management, analysis, visualization, collaboration, and regulatory adherence. The scope of online statistical software within the context of clinical trials and preclinical investigations is substantial and portends significant development in the forthcoming years.

Data Management: Online statistical software offers a proficient avenue for effectively handling voluminous datasets generated during clinical trials and preclinical studies. It empowers researchers to securely store, organize, and analyze data in a centralized manner, ensuring data integrity and accessibility.

Statistical Analysis: These software tools provide an expansive array of statistical methods and algorithms to analyze gathered data. They can perform intricate computations, generate graphical insights, conduct hypothesis testing, and visualize results graphically.

Visual Representation: Online statistical software furnishes a variety of visualization options, such as charts, graphs, and plots, to succinctly exhibit research findings. Visual depictions aid in comprehending intricate data relationships and facilitate informed decision-making.

Collaborative Access: Researchers utilizing online statistical software can collaborate seamlessly with team members situated anywhere in the world. It facilitates real-time data sharing, analysis outcomes, and report dissemination, fostering efficient collaboration even in remote work scenarios.

Regulatory Adherence: Rigorous regulatory requirements govern clinical trials and preclinical investigations. Online statistical software aids researchers in complying with these mandates by offering features like audit trails, version control, secure data transfer protocols, and alignment with data security regulations.

Real-time Monitoring: Certain online statistical software platforms incorporate real-time monitoring capabilities, enabling researchers to continuously track study progress. This feature aids in early identification of issues or deviations during the trial or study period.

Integration of Machine Learning: With the escalating prominence of machine learning in healthcare research, online statistical software can integrate these techniques for predictive modeling and pattern recognition tasks pertinent to clinical trials and preclinical studies.

The future prospects for online statistical software in this domain are promising:

Enhanced Adoption: As more entities recognize the advantages of employing online statistical software for clinical trials and preclinical studies, the adoption rate is poised to increase. This trend will be driven by the demand for efficient data management, advanced statistical analysis, and collaborative capabilities.

Integration with Allied Tools: Online statistical software is poised to seamlessly integrate with other research tools and platforms, including electronic data capture systems, electronic health records, and laboratory information management systems. This integration will streamline data flow and enhance interoperability.

Advancements in Advanced Analytics: The evolution of online statistical software hinges on its ability to offer advanced analytics capabilities, encompassing predictive modeling, machine learning algorithms, and artificial intelligence techniques. These advancements will empower researchers to glean deeper insights from their data, facilitating more informed decision-making.

Cloud-based Solutions: The scalability, flexibility, and cost-effectiveness of cloud computing will play a pivotal role in the evolution of online statistical software. The anticipated trend is the utilization of cloud-based infrastructure to efficiently manage large datasets and provide on-demand computing resources.

Augmented Regulatory Compliance: Given the mounting regulatory scrutiny in clinical trials and preclinical studies, online statistical software will continue evolving to meet compliance requirements more effectively. This entails enhancements in security measures, audit trail functionalities, and automated reporting mechanisms.

6. SUMMARY AND CONCLUSION:

Statistical analysis software programs are specialized tools designed to enable users to conduct intricate statistical analyses. These programs typically provide functionalities for data organization, interpretation, and presentation of selected datasets. A wave of innovation is currently reshaping the pharmaceutical industry, encompassing novel treatment solutions, intelligent tools, advanced analytics, and cutting-edge research. This compilation offers insights and strategies to leverage these advancements, thereby enhancing workforce capabilities, quality, efficiency, and adaptability within pharmaceutical operations. The selection of measurable techniques in clinical research is influenced by factors such as the nature of the event, the number of groups under study, and the study's objectives. The prudent application of measurable methods, rooted in data type and relevant assumptions, is pivotal to ensure accurate conclusions and meaningful insights in the realm of healthcare management.

The application of statistics in clinical and preclinical trials empowers clinical analysts to derive rational and accurate inferences from gathered data, making informed decisions despite inherent uncertainties. Statistics play a pivotal role in mitigating errors and biases in medical research. Biostatistics, in particular, plays a crucial role in assessing treatment efficacy (i.e., its effectiveness) and determining the safety of interventions for patients, encompassing measurements of toxicity levels in both clinical and preclinical trial settings. Statistical analysis software occupies a critical position across diverse fields, aiding researchers in the interpretation of data and facilitating informed decision-making. The expanding landscape of these tools contributes significantly to elevating research outcomes and fostering well-informed conclusions.

REFERENCES:

1. Zahir H, Javaid A, Rehman R, Hussain Z. Statistical concepts in biology and health sciences. *Journal of Ayub Medical College Abbottabad*. 2014 Mar 1;26(1):95-7.
2. Kern SE. Inferential statistics, power estimates, and study design formalities continue to suppress biomedical innovation. *arXiv preprint arXiv:1411.0919*. 2014 Nov 4.
3. Vrijens B, Urquhart J. Methods for measuring, enhancing, and accounting for medication adherence in clinical trials. *Clinical Pharmacology & Therapeutics*. 2014 Jun;95(6):617-26.
4. Denny KH, Stewart CW. Acute, subacute, subchronic, and chronic general toxicity testing for preclinical drug development. In *A comprehensive guide to toxicology in nonclinical drug development 2017 Jan 1* (pp. 109-127). Academic Press.
5. Liu Z, HuiMingalone CK, Gnanatheepam E, Hollander JM, Zhang Y, Meng J, Zeng L, Georgakoudi I. Label-free, multi-parametric assessments of cell metabolism and matrix remodeling within human and early-stage murine osteoarthritic articular cartilage. *Communications Biology*. 2023 Apr 13; 6(1):405.

6. Shah N, Engineer S, Bhagat N, Chauhan H, Shah M. Research trends on the usage of machine learning and artificial intelligence in advertising. *Augmented Human Research*. 2020 Dec;5:1-5.
7. Japac L, Kreuter F, Berg M, Biemer P, Decker P, Lampe C, Lane J, O'Neil C, Usher A. Big data in survey research: AAPOR task force report. *Public Opinion Quarterly*. 2015 Jan 1;79(4):839-80.
8. Farrell, D., 2016. DataExplore: An application for general data analysis in research and education. *Journal of Open Research Software*, 4(1).
9. Arribas J, Bernal D, Fernández-Prades C, Closas P, Fernández-Rubio JA. A novel real-time platform for digital beamforming with GNSS software defined receivers. In *Proceedings of the 22nd International Technical Meeting of the Satellite Division of The Institute of Navigation (ION GNSS 2009)* 2009 Sep 25 (pp. 2329-2343).
10. Mo L. Examining the reliability of logistic regression estimation software (Doctoral dissertation, Kansas State University).
11. Swift ML. GraphPad prism, data analysis, and scientific graphing. *Journal of chemical information and computer sciences*. 1997 Mar 24;37(2):411-2.
12. Dudley WN, Benuzillo JG, Carrico MS. SPSS and SAS programming for the testing of mediation models. *Nursing Research*. 2004 Jan 1;53(1):59-62.
13. Horton NJ, Kleinman K. Using R and RStudio for data management, statistical analysis, and graphics. CRC Press; 2015 Mar 10.
14. Divisi D, Di Leonardo G, Zaccagna G, Crisci R. Basic statistics with Microsoft Excel: a review. *Journal of thoracic disease*. 2017 Jun;9(6):1734.
15. Helsel DR. *Statistics for censored environmental data using Minitab and R*. John Wiley & Sons; 2011 Dec 14.
16. You S, Xie X, Chen Y. Statistical analysis of educational testing data based on SCILAB. In *2009 IEEE International Workshop on Open-source Software for Scientific Computation (OSSC)* 2009 Sep 18 (pp. 81-84). IEEE.
17. Hansen JS. *GNU Octave: Beginner's Guide: Become a proficient octave user by learning this high-level scientific numerical tool from the ground up*. Packt Publishing Ltd; 2011 Jun 21.
18. Xu TT, Peng JL, Ding F. Linkage Relationship between Port Logistics and Regional Economy based on Eviews Software. *J. Softw..* 2013 Apr 1;8(4):971-8.
19. Kremelberg D. *Practical statistics: A quick and easy guide to IBM® SPSS® Statistics, STATA, and other statistical software*. SAGE publications; 2010 Mar 18.
20. Sall J, Stephens ML, Lehman A, Loring S. *JMP start statistics: a guide to statistics and data analysis using JMP*. Sas Institute; 2017 Feb 21.
21. Stevenson KJ. Review of originpro 8.5. *Journal of the American Chemical Society*. 2011 Apr 13;133(14):5621.
22. Chen DG, Peace KE. *Applied meta-analysis with R*. Crc press; 2013 May 3.
23. Van den Ende J, Kemp R. Technological transformations in history: how the computer regime grew out of existing computing regimes. *Research policy*. 1999 Nov 1;28(8):833-51.
24. Kuleto V, Ilić M, Dumangiu M, Ranković M, Martins OM, Păun D, Mihoreanu L. Exploring opportunities and challenges of artificial intelligence and machine learning in higher education institutions. *Sustainability*. 2021 Sep 18;13(18):10424.
25. Ramya R, Rajeswari G. CLOUD TECHNOLOGIES IN EDUCATIONAL RESEARCH. *EDUCATION 5.0: REVOLUTIONIZING LEARNING FOR THE FUTURE*. 2023:90.
26. Larsson S, Anneroth M, Felländer A, Felländer-Tsai L, Heintz F, Ångström RC. Sustainable AI: An inventory of the state of knowledge of ethical, social, and legal challenges related to artificial intelligence.
27. Pugh SL, Torres-Saavedra PA. Fundamental statistical concepts in clinical trials and diagnostic testing. *Journal of Nuclear Medicine*. 2021 Jun 1; 62(6):757-64.
28. Morandat F, Hill B, Osvald L, Vitek J. Evaluating the design of the R language: Objects and functions for data analysis. In *ECOOP 2012—Object-Oriented Programming: 26th European*

- Conference, Beijing, China, June 11-16, 2012. Proceedings 26 2012 (pp. 104-131). Springer Berlin Heidelberg.
29. Truong K (13 August 2019). "GraphPad acquires University of Chicago spinout SnapGene". MedCity News. Breaking Media. Retrieved 23 August 2021.
 30. Mitteer DR, Greer BD, Fisher WW, Cohrs VL. Teaching behavior technicians to create publication-quality, single-case design graphs in graphpad prism 7. *Journal of Applied Behavior Analysis*. 2018 Oct; 51(4):998-1010.
 31. Harris S, Harris D. *Digital design and computer architecture*. Morgan Kaufmann; 2015 Apr 9.
 32. Kaeslin H. *Digital integrated circuit design: from VLSI architectures to CMOS fabrication*. Cambridge University Press; 2008 Apr 28.
 33. Ramirez-Lassepas M, Espinosa CE, Cicero JJ, Johnston KL, Cipolle RJ, Barber DL. Predictors of intracranial pathologic findings in patients who seek emergency care because of headache. *Archives of neurology*. 1997 Dec 1; 54(12):1506-9.