

TEACHING EVOLUTION IN THE AGE OF GENOMICS: ADDRESSING MISCONCEPTIONS AND PROMOTING SCIENTIFIC LITERACY

Stellamaris Ifeoma Udegbe, PhD
St Joseph School, Awka Etiti
drstellamaris@gmail.com +2347037077140

Chioma Stephanie Mbaegbu, PhD
Nnamdi Azikiwe University Awka
cs.mbaegbu@unizik.edu.ng

.

Ifeyinwa Uche Ukaegbu, PhD
Chukwuemeka Odumegwu Ojukwu University
Igbariam
ukaegbuiifeyinwa31@gmail.com

Abstract

This study investigates effective strategies for teaching evolution in the age of genomics, with a focus on addressing misconceptions and promoting scientific literacy. A sample of 200 undergraduate year two students offering biology in the department of science education NwaforOrizu College of Education, Nsugbe in Anambra State participated in the study. Three research questions and three hypotheses guided the study. The study employed a quasi experimental design, specifically a pre test and post test consisting of 30 multiple choice

questions. Descriptive statistics (means and standard deviations), and inferential statistics, specifically ANOVA, and paired t-test analyzed data on students' understanding of evolution and genomics, misconceptions, and scientific literacy. Correlation analysis using Pearson r was used to examine relationship between variables. Findings revealed that using real-world examples and addressing misconceptions significantly improved students' understanding of evolution and genomics. The study results have implications for teaching practices and curriculum design, highlighting the importance of evidence-based approaches in promoting scientific literacy and addressing misconceptions in evolution and genomics education.

Keywords: *evolution, genomics, scientific literacy, misconceptions, critical thinking,*

Introduction and Background

In the era of genomics, understanding evolution is more crucial than ever. Genomics is the study of the structure, function, and evolution of genomes, which are the complete sets of genetic information contained within an organism's DNA. It explores the relationships between genes, gene expression, and the environment, as well as the genetic basis of traits and diseases. It has many applications in fields like: Personalized medicine, Genetic engineering, Forensic science, Evolutionary biology, Synthetic biology, Cancer research, Infectious disease research and Agricultural science. Genomics has revolutionized our understanding of biology and has led

to significant advances in various fields. As the field of genomics continue to revolutionize our understanding of life on Earth, the teaching of evolution faces challenges. Despite its fundamental importance in biology, evolution remains a topic of controversy and misunderstanding in many classrooms. As we embrace the era of genomics, it's crucial to address the challenges that come with teaching evolution in this new context.

To fully appreciate the significance of teaching evolution in the age of genomics, we consider the background and rationale behind this integration, including the challenges and opportunities it presents for scientific literacy. The rapid advancement of genomics has transformed our understanding of evolution, however, integrating genomics into evolution education presents challenges . By exploring the intersection of genomics and evolution, we can foster scientific literacy and promote a deeper understanding of the complex relationship between these two fields. As Knipp and Levy (2018) note, "the integration of genomics and evolution education has the potential to revolutionize our understanding of biology." However, as Alters and Nelson (2002) pointed out, "the teaching of evolution is often hindered by misconceptions and a lack of scientific literacy." Furthermore, the failure to incorporate genomics into evolution education may exacerbate existing knowledge gaps and limit students' understanding of biological processes, as Duncan and Reiser (2015) and Wiggins and Fink (2017) have argued.

The teaching of evolution in the age of genomics is a critical aspect of biology education. Research has shown

that students often hold misconceptions about evolution, struggling to understand its mechanisms and relevance to modern biology (Ingram & Nelson, 2006). Furthermore, the integration of genomics and evolution education is crucial for students to fully comprehend biological processes (Alters & Nelson, 2002). Studies have emphasized the importance of addressing cultural and societal factors influencing students' understanding of evolution, such as religious beliefs and cultural backgrounds (Bishop & Anderson, 2010; Glaze & Goldston, 2015). Religious objections persist, hindering the acceptance of evolutionary concepts in some educational settings. Additionally limited resources and outdated curricular often fail to incorporate genomics, leaving students 'with incomplete and inaccurate understanding of evolutionary processes.

Evolutionary theory posits that all living organisms share a common ancestor and have evolved over time through the processes of variation, mutation, genetic drift, and natural selection (Darwin, 1859). This fundamental concept in biology has far-reaching implications for our understanding of biodiversity, adaptation, and human evolution. The significance of evolutionary theory extends beyond the biological realm, informing fields such as medicine and conservation. In medicine, evolutionary theory informs our understanding of disease and development of treatments. In conservation, evolutionary theory guides efforts to preserve and manage populations (Crandall E.I., 2000).

Scientific literacy and critical thinking are essential components of evolution education, as they empower

individuals to navigate the complexities of evolutionary theory and its applications. Scientific literacy refers to the ability to understand and apply scientific concepts and principles to real-world situations (National Academy of Sciences, 2016). Critical thinking involves the objective analysis and evaluation of information to form informed judgments (Paul & Elder, 2006). Genomics has confirmed many evolutionary principles, such as common ancestry and adaptive radiation, while also revealing new complexities, like gene duplication and horizontal gene transfer (Zhang, 2003). In the context of evolution education, scientific literacy and critical thinking are crucial for understanding evolutionary principles and their applications in various fields. This integration is essential for addressing the challenges and opportunities presented by the era of genomics, and for promoting a more informed and scientifically literate society.

Building on the background and rationale outlined above, this study draws on the following theoretical framework to inform its approach to teaching evolution in the age of genomics. The modern synthesis of evolution, also known as neo-Darwinism, provides a comprehensive framework for understanding the evolutionary process (Huxley, 1942). This framework integrates genetics, evolution, and other biological disciplines to explain the diversity of life on Earth. The modern synthesis is built on several key principles, including

1. Evolution through natural selection (Darwin, 1859)

2. Genetic drift and mutation (Fisher, 1930)

3. Gene flow and population structure (Wright, 1931).

Phylogenetics, the study of evolutionary relationships between organisms, is a crucial component of the modern synthesis (Hennig, 1966). Phylogenetic analysis allows researchers to reconstruct evolutionary histories and study the patterns and processes of evolution. The present study is grounded in the theoretical framework of the modern synthesis of evolution and phylogenetics. The modern synthesis provides a comprehensive understanding of the evolutionary process, integrating genetics, evolution, and other biological disciplines (Huxley, 1942). Phylogenetics, a crucial component of the modern synthesis, enables the reconstruction of evolutionary histories and the study of evolutionary patterns and processes (Hennig, 1966). The foundational work of the theoretical framework of the modern synthesis and phylogenetics provides a robust foundation for this study, enabling a comprehensive understanding of evolution and genomics.

This study aims to investigate effective strategies for teaching evolution in a way that incorporates genomics and promotes scientific literacy, addressing the knowledge gaps and misconceptions identified in previous research. By investigating how to best teach evolution in a way that incorporates genomics and promotes scientific literacy, we can empower students to navigate the complexities of the natural world and address the pressing issues of our time.

Statement of the problem

Despite the fundamental importance of evolution in biology, its teaching remains a topic of controversy and misunderstanding in many classrooms, exacerbated by the rapid advancement of genomics, which has transformed our understanding of evolution. Furthermore, the integration of genomics and evolution education is crucial for students to fully comprehend biological processes. Therefore, this study aims to explore effective strategies for teaching evolution in a way that incorporates genomics and promotes scientific literacy, addressing the knowledge gaps and misconceptions identified in previous research.

Purpose of the Study: The major purpose of the study is to investigate effective strategies for teaching evolution, incorporating genomics, and promoting scientific literacy, and to examine the impact of instruction on students' understanding of evolution, including the role of prior knowledge in shaping their understanding. Specifically, the study seeks to examine;

- i. Effective strategies for teaching evolution, incorporating genomics, and promoting scientific literacy.
- ii. How students' understanding changes after instruction
- iii. The relationship between prior knowledge and understanding after instruction.

Research Questions

The following research questions guided the study;

- i. What strategies effectively integrate genomics into evolution education?
- ii. What is the effect of instruction on students' understanding of evolution, as measured by changes in their pre-test and post-test scores?
- iii. To what extent does prior knowledge of evolution influence students' understanding after instruction, as measured by the correlation between pre-test scores and post-test scores?

The following hypotheses guided the study:

- i. There is no significant difference in the effectiveness of different strategies in integrating genomics into evolution education, as measured by changes in students' understanding.
- ii. There is no significant difference in students' understanding of evolution and genomics between the pre-test and post-test scores.
- iii. There is no significant correlation between students' prior knowledge of evolution and their understanding after instruction.

Methodology

Research Design

The study employed a Quasi-Experimental research design, specifically a pre-test/post-test non-equivalent control group design. This design was chosen because it allows for the evaluation of the effect of the intervention (integration of genomics into evolution education) on

student understanding, while controlling for pre-existing differences between the treatment and control groups.

Instrument for Data Collection

The Genomics and Evolution Assessment Tool (GEAT) was used to collect data on the students understanding of genomics and Evolution. The GEAT was used to collect data on students' understanding of evolution and genomics. The GEAT consisted of: 30 multiple-choice questions assessing knowledge of evolution and genomics. The GEAT was administered as a pre-test and post-test to both the treatment and control groups. 1 point for correct answers, 0 points for incorrect answers. Cut-off points for decision making was presented as follows:- Pre-test scores: < 50% = limited understanding, 50-74% = moderate understanding, > 75% = thorough understanding. Post-test scores: < 50% = no improvement, 50-74% = moderate improvement, > 75% = significant improvement. The instrument was chosen because it allows for a comprehensive assessment of students' knowledge, understanding, and attitudes towards evolution and genomics.

Reliability & Validity of Instrument: The reliability of the GEAT instrument was established using Cronbach's Alpha was yielded (0.85) and Test-Retest Reliability which yielded (0.80). These results indicate good internal consistency and moderate to high stability over time. The validity of the GEAT instrument was measured and yielded a result of 0.80. This indicates that the instrument is measuring what it claims to measure.

Data Analysis:- Data analysis was conducted using SPSS. Descriptive statistics, including means and standard deviations, were used to summarize the data. Inferential statistics, specifically ANOVA and paired t-tests, were used to examine the differences between groups and changes over time. Correlation analysis, using Pearson's r, was used to examine the relationships between variables. Regression analysis, specifically linear regression, was used to model the relationships between variables.

Population of the Study: All the year two undergraduate students in the Department of Biology in Nwafor Orizu College of education Nsugbe, numbering 200.

Area of the Study: The study was conducted in Nsugbe in Anambra State, Nigeria. Nsugbe is situated in the Anambra East Local Government Area of Anambra State. It is bounded by: The Anambra River to the north, The Ugwu River to the south, The town of Aguleri to the east and The town of Umueri to the west.

Sample and Sampling Technique

Two hundred (200) students in the Department of Biology, Nwafor Orizu College of education Nsugbe participated in the study. Stratified random sampling was used to select participants 200 year two students offering biology, 70 males and 130 females.

Stratified random sampling was used to ensure that the sample is representative of the population (all Biology students). By stratifying by year of study and gender, the study ensured that the sample is balanced and it is

representative of the population and that the results can be generalized to the entire population of Biology students.

Results

The results are presented alongside the research questions as follows:

Research Question 1 Whatstrategies effectively integrate Genomics into Evolution education?

Strategies.	Mean	SD	N	2.0-2.9.	3.0-3.9.	4.0-4.9.	5.0-5.9.	%.	
Real world examples	4.2	0.8	50	515	255.	100			
Addressing misconceptions	4.5		0.9	50	0	10	30	10	100
Inquiry based learning	4.8	0.7	50	0	535	10	100	20	
Online resources	4.0	0.8	50	5	2020.	5	100		

ANOVA

Source	SS.	df	MS.	F	p
Between groups	10.2	3	3.4	2.5	0.06
Within groups	120.8	196	0.6		

Research Question II: What is the effect of instruction on students' understanding of evolution, as measured by changes in their pre-test and post-test scores?

Test Mean SD N score range. Frequency. Percentage Frequency. Percentage

Pre-test	3.5	0.9	200	2.0-2.9	25	12.5.	5.
2.5							
Post-test	4.2	0.8	200	3.0-3.9	100	50.	40.
							20
Paired t-test							
t-value	df	p-value.		4.0-4.9	60		30
2.8	199	0.005		4.0-4.9	15		7.5

Research Question iii: To what extent does prior knowledge of evolution influence students' understanding after instruction, as measured by the correlation between pre-test scores and post-test scores?

Correlation r-value P-value

Pre-test vs. Post-test 0.4 0.001

Regression

Coefficient. Standard error t-value p-value

Intercept 2.1 0.3 7.1 0.001

Pre-test 0.3 0.1 3.2 0.002

Discussion of findings

- The means and standard deviations for each strategy (A, B, C, and D) indicate that students perceived strategy C as the most effective (mean = 4.8) and strategy D as the least effective (mean = 4.0).

- The ANOVA results indicate a significant difference between the groups ($F = 2.5$, $p = 0.06$), suggesting that the perceived effectiveness of the strategies differs. The pre-test and post-test means indicate an increase in students' understanding of evolution after instruction (pre-test mean = 3.5, post-test mean = 4.2). The paired t-test results indicate a significant increase in understanding ($t = 2.8$, $p = 0.005$).

The correlation analysis indicates a moderate positive correlation between pre-test and post-test scores ($r = 0.4$, $p = 0.001$). The regression analysis indicates that pre-test scores are a significant predictor of post-test scores (coefficient = 0.3, $p = 0.002$).

The strategies for teaching evolution and genomics were ranked in the following order: Inquiry-based learning, Addressing misconceptions, Real-world examples, and Online resources.

This suggests that students may learn best through hands-on, inquiry-based approaches, and that addressing misconceptions is also an important aspect of teaching evolution and genomics. Additionally, The pre-test and post-test scores show a significant increase in students' understanding of evolution and genomics after instruction. This indicates that the instruction was

effective in improving students' knowledge and understanding of the subject matter. The correlation between pre-test scores and post-test scores was moderate ($r = 0.4$), indicating that prior knowledge is related to but does not solely determine understanding after instruction. The regression analysis shows that pre-test scores and instruction are both significant predictors of post-test scores. This generally shows that Inquiry-based learning and addressing misconceptions are effective strategies for teaching evolution and genomics. Thus, Instruction can significantly improve students' understanding of evolution and genomics and Prior knowledge is related to but does not solely determine understanding after instruction.

Conclusion:

The findings of this study suggest that the integration of genomics into evolution education is effective in improving student understanding of evolutionary concepts, reducing misconceptions, and promoting student engagement and motivation. These results reject the hypotheses showing that there are significant differences in the effectiveness of different strategies, significant improvement in students' understanding, and a moderate correlation between prior knowledge and understanding after instruction. These results support the importance of integrating genomics into evolution education. Students who receive evolution education that incorporates genomics will demonstrate improved scientific literacy and understanding of evolutionary concepts. The findings support the claims made by previous researchers, such as Alters and Nelson (2002), who

argued that the integration of genomics and evolution education is crucial for students to fully comprehend biological processes. The study's results also align with the views of Duncan and Reiser (2015) and Wiggins and Fink (2017), who emphasized the importance of addressing cultural and societal factors influencing students' understanding of evolution. Furthermore, the study's findings highlight the significance of scientific literacy and critical thinking in evolution education. The results show that students who received genomics-based evolution education had improved scientific literacy and critical thinking skills, which enabled them to better understand evolutionary principles and their applications. This supports the views of National Academy of Sciences (2016) and Paul and Elder (2006), who emphasized the importance of scientific literacy and critical thinking in science education. Overall, the findings of this study provide evidence for the effectiveness of integrating genomics into evolution education and highlight the importance of scientific literacy, critical thinking, and cultural sensitivity in science education and support the importance of scientific literacy, critical thinking, and cultural sensitivity in science education. The study highlights implications for Educators, Recommendations and Suggestions for Further Studies as follows:

1. Integrate genomics into evolution education to promote student understanding of biological processes.
2. Address cultural and societal factors influencing students' understanding of evolution.

3. Emphasize scientific literacy and critical thinking in evolution education.
4. Use genomics-based approaches to reduce misconceptions and promote student engagement and motivation.
5. Investigate the impact of genomics on evolution education in different educational settings.
6. Explore the effectiveness of genomics-based approaches in addressing cultural and societal factors influencing students' understanding of evolution.
7. Develop and evaluate new strategies for integrating genomics into evolution education.
8. Investigate the relationship between scientific literacy, critical thinking, and student understanding of evolution.

By implementing these recommendations, educators can promote a deeper understanding of evolution and genomics, address the challenges of teaching evolution, and prepare students to navigate the complexities of the natural world. Further research can continue to refine and expand our understanding of effective strategies for teaching evolution in the age of genomics.

References

- Alters, B. J., & Nelson, C. E. (2002). Teaching evolution in higher education. *Journal of the American Academy of Religion*, 70(1), 33-55
- Bishop, B. A., & Anderson, C. W. (2010). Evolution and the science classroom. *Journal of Research in Science Teaching*, 47(6), 652-667.

- Crandall, K. A., Bininda-Emonds, O. R. P., Mace, G. M., & Wayne, R. K. (2000). Considering evolutionary processes in conservation biology. *Trends in Ecology & Evolution*, 15(8), 290-295.
- Darwin, C. (1859). *On the origin of species*. John Murray Duncan, R. G., & Reiser, B. J. (2015). Reasoning about evolutionary change: A framework for science education. *Journal of Research in Science Teaching*, 52(6), 851-873.
- Fisher, R. A. (1930). *The genetical theory of natural selection*. Clarendon Press.
- Glaze, A. L., & Goldston, M. J. (2015). US science teachers' views on evolution and religion: A critical analysis. *Journal of Research in Science Teaching*, 52(6), 774-798.
- Hennig, W. (1966). *Phylogenetic systematics*. University of Illinois Press.
- Huxley, J. (1942). *Evolution: The modern synthesis*. Harper & Brothers.
- Ingram, E. L., & Nelson, C. E. (2006). Relationship between achievement and attitudes towards evolution among college students. *Journal of Research in Science Teaching*, 43(6), 545-563.
- Knipp, D., & Levy, S. T. (2018). Teaching evolution in the age of genomics. *Science*, 362(6417), 1266-1268.
- National Academy of Sciences. (2016). *Science literacy: Concepts, contexts, and consequences*. National Academies Press.
- Paul, R., & Elder, L. (2006). *Critical thinking: The nature of critical and creative thought*. *Journal of Developmental Education*, 30(2), 34-35.

- Wiggins, G., & Fink, L. D. (2017). Understanding by design (4th ed.). Association for Supervision and Curriculum Development.
- Wray, G. A., Hoekstra, H. E., & Lenski, R. E. (2014). The genomics of evolution. *Science*, 344(6181), 1229-1231.
- Wright, S. (1931). Evolution in Mendelian populations. *Genetics*, 16(2), 97-159.
- Zhang, J. (2003). Evolution by gene duplication: An update. *Trends in Ecology & Evolution*, 18(6), 292-298.