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THE ROLE OF VISUAL EDUCATIONAL TECHNOLOGIES IN TEACHING HUMAN GENETICS

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Abstract.
This article examines the role of visual educational technologies (3D models, interactive simulations, virtual reality (VR), augmented reality (AR), and animations) in teaching human genetics. The study, structured within the IMRAD framework, analyzes the impact of visual aids on student's understanding, retention, and application. The results of the study, based on theoretical and practical materials, show that visual technologies increase the mastery of complex genetic concepts (e.g., DNA replication, gene expression, mutations, and inheritance patterns) by 25-40%. Recommendations for practical application in higher education institutions of Uzbekistan are given.

Keywords:
human genetics, visual educational technologies, 3D modeling, VR/AR, interactive simulations, biology teaching, pedagogical technologies.

Login. Man genetics to be trained is one of the main directions of modern biology education. Genetic concepts involve complex processes at the molecular level, which can be abstract and difficult for students. Traditional methods (verbal explanation, 2D drawings) are often insufficient to maintain student attention and achieve deep understanding.

Visual learning technologies help solve this problem. 3D models, interactive animations, and virtual laboratories allow students to “see” and “manipulate” genetic processes. For example, the double-helix structure of DNA or the consequences of genetic mutations can be observed in real time.

Although biology and genetics education is developing in Uzbekistan, the use of digital and visual technologies is still insufficient. This article proposes ways to evaluate the effectiveness of visual aids and integrate them into the educational process . The purpose of the study: to determine the impact of visual technologies in teaching human genetics.

Man genetics — human hereditary and variability characteristics, from generation to generation transition laws and hereditary diseases the science of learning.

Man organism biological features because of genetics science special **study** uses the following **methods**:

- **Genealogical method:** The person genealogy (lineage) to compose through of characters from generation to generation the passage observation. Hereditary diseases in determining the most wide widespread method.
- **Gemini method:** One from an egg (one) kind to the genotype has) and different from egg developed twins between similarity and the differences analysis to do . This heredity and environment the impact to differentiate help gives.

❖ **Cytogenetic method:** Chromosomes microscope under number and structure study . Down , Klinefelter such as hereditary diseases in determining is used.

❖ **Biochemical method :** Blood, urine and other liquids analysis to do based on substances exchange detection of disorders (for example, phenylketonuria).

❖ **Population statistics method:** Specific in the area resident people in the group some genes and hereditary of diseases spread frequency calculation.

❖ **Molecular genetics method:** DNA and RNA structure directly study, gene mutations to determine.

Tasks: literature analysis, methods description, results and discussions transfer .

Methods. Research mixture in a way was held.

1. Theoretical analysis: International and local literature (2018-2025) was studied. Main sources: Learn.Genetics (University of Utah), NHGRI Teaching Tools, Uzbekistan Higher Education Programs.

2. Practical experiment : 2025-2026 academic year in the year Jizzakh state pedagogy university under Tourist attraction academic high school education 92 people in the institution student participation (2 groups : Mendel — visual technologies with , Morgan — traditional methods with).

- **Visual tools :**
  - ✓ 3D models (PyMOL, DNA for Chimera, proteins).
  - ✓ Interactive simulations (Learn.Genetics, Population Genetics Explorer).
  - ✓ VR/AR applications (simple genome browsers and DNA visualizer).
  - ✓ Animations (DNA replication , transcription).

3. Evaluation :

❖ Pre-and post-tests (20 questions, knowledge, comprehension, and application levels).

❖ Questionnaires (Likert scale).

❖ Observation and interviews. Data were statistically analyzed using SPSS software (t-test, $p<0.05$).

The study was conducted in accordance with ethical requirements.

Results . Mendel in the group The average score increased from 48% in the pre- test to 82% in the post-test (+34%). In the Morgan group and +18% ($p<0.01$).

Results on complex topics :

- DNA structure and replication: 91% correct answers in the visual group (62% in the control).
- Gene-genetic linkage and mutations: +42% difference.
- Phenotype and genotype concepts: visual aids reduced student errors by 2 times.

Survey results: 87% of students rated visual technologies as “very effective.” 76% of them responded that they “understood abstract concepts better.” Students who used VR/AR were more motivated .

are not sufficient in Uzbekistan, good results have been achieved using simple 3D printers and free online resources (Learn.Genetics).

Discussion . Results international research with suitable comes: visualization genetic inheritance and heredity in learning students understand noticeable at the level Visual technologies cognitive the load reduces and two one-sided coding according to the theory (Paivio) more efficient to master provides.

In Uzbekistan problems: technical There is a lack of infrastructure, teacher qualifications, and software. However, the digital transformation policy (2020-2025) will allow this direction to develop.

Limitations: sample size is limited, long-term effects have not been studied. Future research for : with AI integrated personal genetic simulators .

Conclusion when visual education technologies man genetics plays an important role in teaching. They improve the quality of students knowledge, arouse interest, and form practical skills. It is recommended to widely introduce these technologies into the education system of Uzbekistan: training for teachers, creation of a free resource base, and hybrid learning models.

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