Science Education Quarterly, 2026, Vol. **3**, Iss. 2, pp. 79–91 10.55056/seq.1162

Effect of online animation among Southwest Nigerian biology undergraduates achievement in genetics

Abigeal Anuoluwapo Otemuyiwa[1], Olusegun Emmanuel Ogundele[2] and Joy Abiola Onipede[3]

[1]Department of General Studies in Education, Federal College of Education, Abeokuta-Ibadan Rd., Abeokuta 110121, Ogun State, Nigeria

[2]Department of Biological Sciences, Tai Solarin Federal University of Education, Ijagun Rd., Ijebu Ode 120103, Ogun State, Nigeria

[3]Biology Department, Federal College of Education, Abeokuta-Ibadan Rd, Abeokuta 110121, Ogun State, Nigeria

Abstract. Genetics, the study of heredity and genetic variation, is vital to biology education. Genome sequencing (GS), which decodes an organism's entire DNA, represents a major advance in the field yet remains difficult for students to grasp due to its abstract nature and the predominance of traditional lecture-based instruction. This study examined the effect of online animation on genetics achievement using a quasi-experimental design involving 100 second-year biology undergraduates from Tai Solarin University of Education (TASUED) and Lagos State University of Education (LASUED), Nigeria. Students were purposively selected and randomly assigned to experimental (animation) and control (lecture-based) groups. Items adapted from the Knowledge and Attitude Toward Genome Sequencing questionnaire (reliability $\alpha = 0.79$) were administered over a 12-week intervention. Data analysis showed significant improvement in objective knowledge in both groups, with higher gains in the experimental group. Subjective knowledge showed no significant gains, consistent with a ceiling effect at baseline. Animations improved attitudes toward genome sequencing ($p = 0.014$), and satisfaction with the animated materials was high. The study recommends incorporating animations into biology teaching to enhance learning outcomes.

Keywords: genetics, genome sequencing, online animation, biology undergraduates

1. Introduction

Biology is the scientific study of life across multiple levels of organization, from molecules and cells to organisms, populations, and ecosystems [21]. Genetics, a foundational branch of this discipline, investigates heredity and variation, providing insight into how traits are transmitted across generations, how genetic mutations arise, and how the environment shapes gene expression [2]. The discipline has evolved considerably since Gregor Mendel's early work on pea plants, expanding to encompass molecular genetics, population genetics, and genomics. At the undergraduate level, genetics serves as a core subject because of its applications in health, agriculture, biotechnology, and evolutionary biology [4].

One major topic within genetics is genome sequencing (GS), the process of decoding the complete DNA sequence of an organism. Understanding GS is essential for biology undergraduates because it underpins advanced research in molecular biology and biotechnology [18]. The central dogma of molecular biology, which describes the directional flow of genetic information from DNA to RNA to protein, provides the conceptual framework within which GS is situated [7], and GS itself enables scientists to identify the variants and mutations that underlie inherited conditions and disease susceptibility [10]. Despite its importance, many undergraduates struggle with GS because they

0009-0006-5423-076X (A. A. Otemuyiwa); 0000-0001-7995-7021 (O. E. Ogundele); 0000-0002-5567-741X (J. A. Onipede)
abigealanu94@gmail.com (A. A. Otemuyiwa); ogundeleoe@tasued.edu.ng (O. E. Ogundele); jaonipede@yahoo.com (J. A. Onipede)

Received	Accepted	Published	Version of record
2025-08-19	2026-02-27	2026-03-25	2026-03-25

Science Education Quarterly

© Copyright for this article by its authors, published by the Academy of Cognitive and Natural Sciences. This is an Open Access article distributed under the terms of the Creative Commons License Attribution 4.0 International (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

find it abstract and difficult to visualize [11]. Traditional lecture-based instruction compounds this difficulty by encouraging memorization over conceptual understanding, which is associated with poor academic performance [17].

The growth of digital technology has introduced new instructional possibilities. Online animation, which uses moving graphics and narrated visuals to represent dynamic biological processes, is one such tool [23]. By translating abstract information into concrete visual sequences, animation can reduce the cognitive effort required to build mental models of complex processes and support learning across diverse student populations [8, 14, 20]. In biology education, the value of animation has been demonstrated for topics including the circulatory system [16] and DNA structure [5]. Rogers, Orado and Nasibi [16] used a quasi-experimental design with secondary school students in Kenya and found that 3D animation produced higher post-test scores and better visualization of blood flow than traditional instruction. Duru, Uko and Utibe [5] compared animation, improvised models, realia, and conventional teaching among 879 Nigerian secondary students and found that all three innovative approaches outperformed conventional instruction, with the animation group demonstrating notably better recall of DNA base pairing and chromosome organization.

Despite these promising findings, research specifically targeting GS among university-level biology students in sub-Saharan Africa remains limited. It is unclear whether online animations produce meaningful gains in objective knowledge of GS, whether they shift students' attitudes toward GS, and how students' self-perceived knowledge relates to their demonstrated understanding. This study addresses those gaps by examining the effect of online animation on the genetics achievement of Southwest Nigerian biology undergraduates. Specifically, it assesses students' subjective and objective knowledge of genetics and GS, their correlation, and students' attitudes and satisfaction in relation to animation-based instruction.

2. Methodology

2.1. Research design

This study adopted a pre-test and post-test quasi-experimental design with an experimental group and a control group. The design examined the effect of online animation on the achievement of Southwest Nigerian biology undergraduates in genetics. Students in each class were randomly assigned to experimental or control groups based on their seating arrangement. The experimental group received instruction using online animations, while the control group received traditional lecture-based instruction covering identical content.

2.2. Participants

The study was conducted at Tai Solarin University of Education (TASUED), Ogun State, and Lagos State University of Education (LASUED), Ijanikin, Lagos State, Nigeria, during the 2024–2025 academic session. Participants were second-year undergraduate biology students enrolled in an introductory genetics course. At TASUED, 29 students were assigned to the experimental group and 29 to the control group. At LASUED, 22 students were assigned to the experimental group and 20 to the control group, giving a total of 51 students in the experimental group and 49 in the control group ($N = 100$). With respect to age, 59 participants were between 16 and 20 years, 39 were between 21 and 25 years, and 2 were between 26 and 30 years.

2.3. Instruments

Academic achievement was measured using the Genetics Achievement Test, adapted from the Knowledge and Attitude towards Genome Sequencing (KAGS) instrument [9]. The test consisted of ten multiple-choice items covering key concepts in genetics and GS, including DNA, gene, chromosome, genome, and genome sequencing. Each correct response was scored one mark; incorrect or "do not know" responses were scored zero, giving a maximum score of ten. Higher scores indicated greater academic achievement.

Content validity was established through expert review by two biology education specialists and one measurement and evaluation expert, who verified item clarity and alignment with course objectives. A pilot study with a comparable group of undergraduate biology students yielded a Cronbach alpha coefficient of 0.79, indicating acceptable internal consistency.

2.4. Procedure

The intervention lasted twelve weeks. During the first two weeks, a pre-test was administered to both groups to establish baseline achievement. The experimental group then received instruction through two structured online animation videos: *My Genome Sequence, Part 1* (duration: 2 min 27 s) and *My Genome Sequence, Part 2* (duration: 2 min 26 s). Each animation was shown during scheduled lecture periods and followed by guided explanation and discussion. The control group received equivalent genetics content through traditional lecture methods, including verbal explanation, board illustrations, and class discussion.

To prevent contamination, the two groups were taught in separate sessions; while one group received instruction, the other was not present in the classroom. The same instructor taught both groups to minimize instructor-related bias, and the duration, content coverage, and assessment conditions were identical across groups. In weeks eleven and twelve, revision activities were conducted, followed by post-test administration under the same conditions as the pre-test.

2.5. Data analysis

Data were analysed using descriptive and inferential statistics with SPSS version 22. Means and standard deviations summarised achievement scores. Paired samples t-tests examined differences between pre-test and post-test scores within each group, and independent samples t-tests compared post-test scores between groups. Pearson correlation coefficients examined the relationship between students' perceived knowledge and their objective achievement scores. All tests were conducted at $\alpha = 0.05$. Cohen's d was computed to indicate the magnitude of within-group pre-to-post differences.

2.6. Ethical considerations

Approval for the study was obtained from the relevant authorities of both institutions. Students were informed of the study purpose, participation was voluntary, and confidentiality of responses was ensured throughout.

3. Results

3.1. Subjective knowledge of genetics and genome sequencing

Table 1 presents pre-test and post-test results for subjective knowledge by institution. At TASUED, the proportion of students reporting a "good understanding of genetics" increased from 69.0% at baseline to 75.9% post-intervention. At LASUED, the corresponding proportion increased from 81.0% to 85.7%. Across both institutions, the majority of students reported familiarity with DNA, gene, chromosome, and genome at baseline, and these proportions changed only marginally. None of the observed shifts were statistically significant, reflecting a strong ceiling effect attributable to high prior familiarity with these foundational concepts.

Table 2 presents the same outcomes disaggregated by treatment group. In the control group, "good understanding of genetics" rose from 73.5% to 81.6%; "heard of DNA" increased from 98.0% to 100%; "heard of chromosome" from 95.9% to 100%; and "heard of genome sequencing" from 89.8% to 91.8%. Awareness of gene and genome remained at 100% throughout. In the experimental group, "good understanding of genetics" increased from 74.5% to 88.2%, and "heard of genome

Table 1
Subjective knowledge of genetics and genome sequencing based on institutions.

Measure	TASUED			LASUED		
	Pre (%)	**Post (%)**	***p*-value**	**Pre (%)**	**Post (%)**	***p*-value**
Understanding of genetics						
Some	18 (31.0)	14 (24.1)	0.29	8 (19.0)	6 (14.3)	0.58
Good	40 (69.0)	44 (75.9)		34 (81.0)	36 (85.7)	
Heard of DNA						
Yes	58 (100.0)	58 (100.0)	>0.05	41 (97.6)	42 (100.0)	0.33
No	0 (0.0)	0 (0.0)		1 (2.4)	0 (0.0)	
Heard of gene						
Yes	58 (100.0)	58 (100.0)	>0.05	42 (100.0)	42 (100.0)	>0.05
Heard of chromosome						
Yes	56 (96.6)	58 (100.0)	0.16	42 (100.0)	42 (100.0)	>0.05
No	2 (3.4)	0 (0.0)		0 (0.0)	0 (0.0)	
Heard of genome						
Yes	58 (100.0)	58 (100.0)	>0.05	42 (100.0)	42 (100.0)	>0.05
Heard of GS						
Yes	54 (93.1)	54 (93.1)	>0.05	35 (83.3)	41 (97.6)	0.33
No	4 (6.9)	4 (6.9)		7 (16.7)	1 (2.4)	
Knowledge of DNA						
Yes	58 (100.0)	58 (100.0)	>0.05	42 (100.0)	42 (100.0)	>0.05
Knowledge of gene						
Yes	58 (100.0)	58 (100.0)	>0.05	42 (100.0)	42 (100.0)	>0.05
Knowledge of chromosome						
Yes	56 (96.6)	58 (100.0)	0.16	42 (100.0)	42 (100.0)	>0.05
No	2 (3.4)	0 (0.0)		0 (0.0)	0 (0.0)	
Knowledge of genome						
Yes	58 (100.0)	58 (100.0)	>0.05	42 (100.0)	42 (100.0)	>0.05
Knowledge of GS						
Yes	53 (91.4)	54 (93.1)	0.71	37 (88.1)	38 (90.5)	>0.05
No	5 (8.6)	4 (6.9)		5 (11.9)	4 (9.5)	

sequencing" rose from 74.5% to 96.1%. None of these changes reached statistical significance in either group. The absence of significant subjective gains in the experimental group, despite exposure to the animation, indicates that the intervention did not shift students' self-perceptions of knowledge, most likely because awareness of these concepts was already near-ceiling at baseline.

3.2. Objective knowledge of genetics and genome sequencing

Table 3 presents objective knowledge outcomes by institution. At TASUED, a statistically significant pre-to-post improvement was recorded for the item "Genome sequencing can be done on the DNA in a blood sample" ($p = 0.020$); other items did not reach significance. At LASUED, significant improvements were observed on three items ($p = 0.010$, $p = 0.010$, and $p = 0.013$), confirming meaningful gains in conceptual understanding facilitated by the intervention.

Table 4 presents objective knowledge outcomes by treatment group. The experimental group achieved statistically significant pre-to-post improvements on three items: "Our complete set of DNA is called our genome" ($p < 0.001$, $d = 0.92$), "Genome sequencing can be done on the DNA in a blood sample" ($p < 0.001$, $d = 0.87$), and "We know all there is to know about what our genome does"

Table 2
Subjective knowledge of genetics and genome sequencing based on treatments.

Measure	Control			Experimental		
	Pre (%)	Post (%)	*p*-value	Pre (%)	Post (%)	*p*-value
Understanding of genetics						
Some	13 (26.5)	9 (18.4)	0.29	13 (25.5)	6 (11.8)	0.58
Good	36 (73.5)	40 (81.6)		38 (74.5)	45 (88.2)	
Heard of DNA						
Yes	48 (98.0)	49 (100.0)	0.32	45 (88.2)	51 (100.0)	>0.05
No	1 (2.0)	0 (0.0)		6 (11.8)	0 (0.0)	
Heard of gene						
Yes	49 (100.0)	49 (100.0)	>0.05	51 (100.0)	51 (100.0)	>0.05
Heard of chromosome						
Yes	47 (95.9)	49 (100.0)	0.16	51 (100.0)	51 (100.0)	>0.05
No	2 (4.1)	0 (0.0)		0 (0.0)	0 (0.0)	
Heard of genome						
Yes	49 (100.0)	49 (100.0)	>0.05	51 (100.0)	51 (100.0)	>0.05
Heard of GS						
Yes	44 (89.8)	45 (91.8)	0.71	38 (74.5)	49 (96.1)	0.58
No	5 (10.2)	4 (8.2)		13 (25.5)	2 (3.9)	
Knowledge of DNA						
Yes	49 (100.0)	49 (100.0)	>0.05	51 (100.0)	51 (100.0)	>0.05
Knowledge of gene						
Yes	49 (100.0)	49 (100.0)	>0.05	51 (100.0)	51 (100.0)	>0.05
Knowledge of chromosome						
Yes	47 (95.9)	49 (100.0)	0.16	51 (100.0)	51 (100.0)	>0.05
No	2 (4.1)	0 (0.0)		0 (0.0)	0 (0.0)	
Knowledge of genome						
Yes	49 (100.0)	49 (100.0)	>0.05	51 (100.0)	51 (100.0)	>0.05
Knowledge of GS						
Yes	45 (91.8)	43 (87.8)	0.49	37 (72.5)	51 (100.0)	0.08
No	4 (8.2)	6 (12.2)		14 (27.5)	0 (0.0)	

($p < 0.001$, $d = 0.78$). The control group reached significance on two items: "Genome sequencing can be done on the DNA in a blood sample" ($p = 0.004$, $d = 0.43$) and "We know all there is to know about what our genome does" ($p = 0.020$, $d = 0.32$), though with smaller effect sizes than the experimental group. These findings indicate that animation-based instruction produced broader and larger gains in objective knowledge than lecture-based instruction alone, particularly for items requiring understanding of GS procedures and the limits of genomic knowledge.

3.3. Correlation between subjective and objective knowledge

Table 5 presents Pearson correlations between two subjective knowledge indicators – "understanding of genetics" and "knowledge of genome sequencing" – and each of the ten objective knowledge items. Students who reported understanding genetics showed a significant positive correlation with objective item 9 ($r = 0.310$, $p = 0.009$) and item 10 ($r = 0.270$, $p = 0.030$), and a significant negative correlation with item 4 ($r = -0.230$, $p = 0.006$). Students who reported knowledge of GS showed significant positive correlations with item 3 ($r = 0.250$, $p = 0.036$), item 6 ($r = 0.370$, $p = 0.002$), item 8 ($r = 0.510$, $p < 0.001$), item 9 ($r = 0.370$, $p = 0.002$), and item 10 ($r = 0.270$,

Table 3
Objective knowledge of genetics and genome sequencing based on institutions.

Measure	TASUED – Mean (SD)			LASUED – Mean (SD)		
	Pre	Post	p-value	Pre	Post	p-value
Our DNA is inside our cell	0.94 (0.24)	0.94 (0.24)	>0.05	1.00 (0.00)	1.00 (0.00)	>0.05
Our DNA doesn't have an effect on how our body works	0.31 (0.47)	0.54 (0.50)	0.940	0.38 (0.50)	0.71 (0.46)	0.220
Our complete set of DNA is called our genome	0.90 (0.31)	0.98 (0.14)	0.740	0.81 (0.40)	0.95 (0.22)	0.640
Around 1% of our genome is the same as other people's	0.35 (0.48)	0.38 (0.49)	0.400	0.29 (0.46)	0.33 (0.48)	1.000
Our genome is more similar to our close relatives like our mum and dad, than it is with other people's	0.85 (0.36)	0.94 (0.25)	0.470	0.86 (0.36)	0.95 (0.22)	0.690
Genome sequencing involves looking at all the DNA in a person's genome	0.81 (0.39)	0.85 (0.36)	0.750	0.86 (0.36)	0.95 (0.22)	0.010
A glitch in the genome can cause health problems because the body isn't getting the right instructions	0.79 (0.41)	0.83 (0.38)	0.760	0.71 (0.46)	0.86 (0.36)	0.130
Genome sequencing can be done on the DNA in a blood sample	0.73 (0.45)	0.92 (0.28)	0.020	0.86 (0.36)	0.95 (0.22)	0.010
We know all there is to know about what our genome does	0.92 (0.28)	0.94 (0.25)	0.600	0.48 (0.51)	0.76 (0.44)	0.013
If someone with a health problem has genome sequencing, they will always find helpful information about the cause of the problem	0.77 (0.43)	0.90 (0.31)	0.350	0.81 (0.40)	0.95 (0.22)	0.640

$p = 0.025$).

For the remaining items – including those concerning DNA, gene, chromosome, and genome – correlations with both subjective indicators were small and non-significant. This pattern reveals a selective alignment between self-perceived and demonstrated knowledge: students who believed they understood genetics and GS were more likely to answer correctly on items directly related to GS procedures and applications, but self-confidence about foundational terms did not correspond with stronger performance on those specific items. The presence of multiple significant correlations leads to rejection of the null hypothesis that subjective and objective knowledge are unrelated.

3.4. Attitude towards genome sequencing

Table 6 compares post-intervention attitudes between treatment groups. Two items yielded statistically significant group differences. A higher proportion of experimental group students described GS as "a good thing" compared with control group students (96.1% vs. 69.4%, $p = 0.014$), and all experimental group students rated GS as "interesting" compared with 83.7% of control group students ($p = 0.050$). The experimental group also showed a notably higher rate of wanting more information before deciding to undergo GS ($p < 0.001$), suggesting more deliberate engagement with the topic rather than passive acceptance. Differences on items concerning perceived benefits, perceived limitations, ease of decision-making, and perceptions of GS as harmful or helpful did not reach statistical significance, indicating that attitude change was selective rather than uniform. Nonetheless, the significant shifts on valence and interest items suggest that animation fostered more positive

Table 4
Objective knowledge of genetics and genome sequencing based on treatments.

Measure	Control – Mean (SD)			Experimental – Mean (SD)		
	Pre	Post	p-value	Pre	Post	p-value
Our DNA is inside our cell	0.94 (0.24)	0.94 (0.24)	>0.05	1.00 (0.00)	1.00 (0.00)	>0.05
Our DNA doesn't have an effect on how our body works	0.35 (0.48)	0.53 (0.50)	0.240	0.30 (0.47)	0.75 (0.44)	0.600
Our complete set of DNA is called our genome	0.86 (0.35)	0.96 (0.20)	0.570	0.90 (0.31)	1.00 (0.00)	<0.001
Around 1% of our genome is the same as other people's	0.25 (0.44)	0.37 (0.49)	0.340	0.30 (0.47)	0.60 (0.50)	0.710
Our genome is more similar to our close relatives like our mum and dad, than it is with other people's	0.90 (0.31)	0.90 (0.31)	0.440	0.95 (0.22)	0.85 (0.37)	0.690
Genome sequencing involves looking at all the DNA in a person's genome	0.80 (0.41)	0.86 (0.35)	0.570	0.90 (0.31)	0.95 (0.22)	0.750
A glitch in the genome can cause health problems because the body isn't getting the right instructions	0.78 (0.42)	0.84 (0.37)	0.270	0.75 (0.44)	0.85 (0.37)	0.740
Genome sequencing can be done on the DNA in a blood sample	0.74 (0.45)	0.90 (0.31)	0.004	0.85 (0.37)	1.00 (0.00)	<0.001
We know all there is to know about what our genome does	0.71 (0.46)	0.84 (0.37)	0.020	0.95 (0.22)	1.00 (0.00)	<0.001
If someone with a health problem has genome sequencing, they will always find helpful information about the cause of the problem	0.82 (0.39)	0.90 (0.31)	0.200	0.70 (0.47)	0.95 (0.22)	0.530

affective and cognitive engagement with GS than lecture-based instruction.

3.5. Satisfaction with animation

Table 7 summarises satisfaction responses from experimental group students only, as only that group was exposed to the animation. Overall satisfaction was high: 84.3% of students found the animation easy or very easy to understand, 86.3% rated the amount of information as appropriate, and 86.3% rated its length as appropriate. All students reported liking the animation's appearance, and all 51 experimental group students reported learning something new. A further 94.1% indicated they would find the animation helpful if making a real decision about undergoing GS. These results suggest that the animated materials were well-matched to students' needs in terms of clarity, pacing, and informational depth.

Table 5
Correlation of subjective and objective knowledge of genetics and genome sequencing.

№	Measure	Understanding of genetics	Knowledge of genome sequencing
1	Our DNA is inside our cell	−0.090 (0.420)	0.190 (0.130)
2	Our DNA doesn't have an effect on how our body works	0.090 (0.470)	0.060 (0.630)
3	Our complete set of DNA is our genome	−0.080 (0.520)	0.250 (0.036)
4	Around 1% of our genome is the same as other people's	−0.230 (0.006)	0.009 (0.940)
5	Our genome is more similar to our close relatives like our mum and dad, than it is with other people's	−0.050 (0.700)	0.490 (0.690)
6	Genome sequencing involves looking at all the DNA in a person's genome	0.190 (0.110)	0.370 (0.002)
7	A glitch in the genome can cause health problems because the body isn't getting the right instructions	0.009 (0.940)	0.150 (0.230)
8	Genome sequencing can be done on the DNA in a blood sample	0.019 (0.880)	0.510 (0.000)
9	We know all there is to know about what our genome does	0.310 (0.009)	0.370 (0.002)
10	If someone with a health problem has genome sequencing, they will always find helpful information about the cause of the problem	0.270 (0.030)	0.270 (0.025)

Note: Values represent correlation coefficients with p-values in parentheses.

4. Discussion

This study found that online animation produced significantly larger gains in objective knowledge of genetics and GS than lecture-based instruction, while neither instructional approach significantly increased subjective knowledge. Animation also produced more positive attitudes toward GS on two specific items, and satisfaction with the animated materials was uniformly high. Taken together, these findings are consistent with what three intersecting theoretical frameworks would predict, though each framework also illuminates the boundaries of what animation alone can achieve.

Dual Coding Theory [13] holds that learning is more durable when information is processed simultaneously through both the verbal and the visual channel. Online animation operationalises this by pairing narrated explanation with synchronized motion graphics, so learners encode GS content through both channels in parallel. This accounts for the objective knowledge gains observed in the experimental group: students who processed the animation could subsequently retrieve and apply specific information about GS procedures and the limits of genomic knowledge at levels significantly above their own baseline and above the control group. The ceiling effects visible in the control group – particularly on the two items where it also reached significance – suggest that repeated verbal exposure across twelve weeks provided some dual-channel processing through board illustrations, but the magnitude of change was consistently smaller. Importantly, dual-channel presentation improved what students could demonstrate on objective tests without shifting their self-perceptions of knowledge. Because subjective awareness of GS was already near-ceiling at pre-test, the animation enriched the quality of stored representations without altering students' belief that they already knew the material.

Cognitive Load Theory [19] complements this account by specifying the conditions under which dual-channel processing leads to learning. When instructional materials reduce extraneous mental effort and focus working memory on core content, learners are freed to build accurate mental models. The satisfaction data support this interpretation: 84.3% of experimental group students found the animation easy or very easy to understand, 86.3% rated its informational density as appropriate,

Table 6
Attitude towards genome sequencing comparing treatment groups.

Measure	Control (%)	Experimental (%)	p-value
Would you want to have genome sequencing?			
Yes	25 (51.0)	28 (54.9)	0.630
No	2 (4.1)	0 (0.0)	0.430
Not sure	2 (4.1)	0 (0.0)	0.990
Would want more info before a decision	20 (40.8)	23 (45.1)	<0.001
I understand the benefits of genome sequencing			
Agree	39 (79.6)	46 (90.2)	0.490
Disagree	2 (4.1)	0 (0.0)	0.370
Not sure	8 (16.3)	5 (9.8)	0.380
I understand the limitations of genome sequencing			
Agree	29 (59.2)	33 (64.7)	0.160
Disagree	2 (4.1)	8 (15.7)	0.170
Not sure	18 (36.7)	10 (19.6)	0.360
A decision about genome sequencing would be easy			
Agree	37 (75.5)	38 (74.5)	0.520
Disagree	6 (12.2)	10 (19.6)	0.490
Not sure	6 (12.2)	3 (5.9)	0.700
Genome sequencing is:			
A bad thing	10 (20.4)	0 (0.0)	0.057
A good thing	34 (69.4)	49 (96.1)	0.014
Neither	5 (10.2)	2 (3.9)	0.230
Genome sequencing is:			
Harmful	1 (2.0)	0 (0.0)	0.660
Helpful	47 (95.9)	51 (100.0)	0.490
Neither	1 (2.0)	0 (0.0)	1.000
Genome sequencing is:			
Boring	2 (4.1)	0 (0.0)	0.160
Interesting	41 (83.7)	51 (100.0)	0.050
Neither	6 (12.2)	0 (0.0)	0.360

and all 51 students reported learning something new. These indicators of low perceived difficulty and high perceived gain suggest that the animations were well-calibrated to manage cognitive load. At the same time, Cognitive Load Theory helps explain why significant attitude change was limited to two items rather than appearing across all attitude measures. Optimising cognitive efficiency during a short animation reduces extraneous load but does not automatically produce the extended value-based reflection through which deeper attitudinal commitments are formed. Hammond et al. [6] reached a parallel conclusion in their randomised controlled trial: adolescents found genome sequencing animations enjoyable and easy to understand, yet no statistically significant shift in deeper attitudes or engagement intentions was observed. The present findings extend that pattern to university-level learners in a Nigerian context.

Constructivist theory [22] provides a third complementary lens for interpreting the gap between subjective confidence and objective performance visible in the correlation analysis. Meaningful learning requires learners to actively connect new information to existing knowledge structures and reorganise those structures through guided experience. When this reorganisation is incomplete, learners form partial or imprecise mental models, producing a mismatch between what they believe they understand and what they can demonstrate. The weak and mostly non-significant correlations between subjective indicators and objective items for basic concepts such as DNA, gene, and chromosome reflect this pattern: students reported high confidence in these concepts, but confidence

Table 7
Satisfaction with information in the animation.

Measure	Frequency	Percentage (%)
Was the animation easy or hard to understand?		
Quite hard	8	15.7
Quite easy	28	54.9
Very easy	15	29.4
The amount of information in the animation was:		
Too much	7	13.7
The right amount	44	86.3
The length of the animation was:		
Too long	5	9.8
Too short	2	3.9
The right amount	44	86.3
What did you think about the way the animation looked?		
I liked it very much	28	54.9
I quite liked it	23	45.1
Did you learn anything new?		
Yes	51	100.0
Would you find this animation helpful if making a decision about genome sequencing?		
Yes	48	94.1
Don't know	3	5.9

did not reliably predict correct answers. A similar gap was documented by Alotaibi and Cordero [3], who found that Saudi medical students rated their genomics knowledge as insufficient while objectively achieving approximately 44% correct answers on multiple-choice tests, and by Zakariyah et al. [24], who reported analogous divergence across more than 700 medical students and interns in Saudi Arabia. The selective alignment that did emerge – with subjective GS knowledge significantly predicting correct responses on GS-specific objective items – suggests that students' self-models are more accurate for concepts they have recently engaged with in depth than for foundational terms that were learned earlier and assumed to be fully understood. Constructivist principles therefore support a design implication that extends beyond animation use: instructional interventions should pair visual tools with structured activities that require students to actively apply, connect, and test their understanding, rather than assuming that increased awareness translates automatically into accurate comprehension.

These theoretical interpretations align with and extend prior empirical evidence. Lewis et al. [9] demonstrated that an online animation on GS significantly improved objective genomic knowledge among young people in the United Kingdom, and the present study replicates that core finding with Nigerian undergraduates, confirming cross-contextual generalizability. Adejumo et al. [1] found that Nigerian nursing undergraduates showed only moderate baseline genomic knowledge and received no post-instruction assessment, underscoring that without structured intervention the gap between familiarity and understanding persists. The gains observed in the current experimental group demonstrate that animation embedded within a scheduled curriculum with guided discussion can produce the kind of meaningful conceptual change that passive familiarity alone does not generate. The high pre-existing subjective knowledge reported by Rini et al. [15] among patients undergoing diagnostic exome sequencing and by Omran et al. [12] across a systematic review of pharmacogenomics educational interventions both produced the ceiling effects on subjective measures that are visible here, confirming that the absence of significant subjective gains reflects an instrument sensitivity issue rather than a failure of the intervention.

5. Conclusion

This study demonstrated that online animations significantly improved objective knowledge of genetics and GS among Southwest Nigerian biology undergraduates, with larger and more consistent gains in the experimental group than in the control group. Subjective knowledge did not increase significantly in either group, a pattern attributable to near-ceiling baseline familiarity rather than to ineffectiveness of the intervention. Animation also produced more favourable attitudes toward GS on measures of perceived valence and interest, and satisfaction with the animated materials was uniformly high. The persistent disconnect between students' self-rated and objectively demonstrated knowledge underscores the need for instructional approaches that move beyond building awareness to fostering accurate and deep conceptual understanding. Embedding animation within curricula that include structured application activities and metacognitive reflection is therefore recommended as the most productive path forward for genetics education in Nigerian tertiary institutions.

6. Recommendations

1. Animation-based instruction should be integrated into undergraduate biology curricula as a complement to, rather than a replacement for, guided discussion and application activities. Lecturers should receive professional development in digital pedagogy, and institutions should invest in the ICT infrastructure necessary to support consistent technology-based teaching.
2. When selecting and deploying animations, instructors should verify scientific accuracy, align each video segment with explicit learning objectives, guide students through the material in structured sequences, and follow viewing with brief formative assessments to identify and address residual misconceptions.
3. Future interventions should incorporate explicit metacognitive components – such as structured self-assessment before and after instruction – to reduce the gap between students' perceived and demonstrated knowledge and to make the depth of conceptual change more visible to both learners and instructors.

References

[1] Adejumo, P.O., Kolawole, I.O., Ojo, I.O., Ilesanmi, R.E., Olorunfemi, O. and Tijani, W.A., 2021. University students' knowledge and readiness to practice genomic nursing in Nigeria. *International Journal of Africa Nursing Sciences*, 15, p.100371. Available from: https://doi.org/10.1016/j.ijans.2021.100371.

[2] Alberts, B., Johnson, A. and Lewis, J., 2015. *Molecular Biology of the Cell*. 6th ed. Garland Science, Taylor and Francis Group.

[3] Alotaibi, A.A. and Cordero, M.A.W., 2021. Assessing Medical Students' Knowledge of Genetics: Basis for Improving Genetics Curriculum for Future Clinical Practice. *Advances in Medical Education and Practice*, 12, pp.1521–1530. Available from: https://doi.org/10.2147/AMEP.S337756.

[4] Collins, F.S., Morgan, M. and Patrinos, A., 2003. The Human Genome Project: Lessons from Large-Scale Biology. *Science*, 300(5617), pp.286–290. Available from: https://doi.org/10.1126/science.1084564.

[5] Duru, C.M., Uko, P.J. and Utibe, U.J., 2023. Effect of DNA animation, improvised model and realia on teaching and students' performance based on school location in Biology in Akwa Ibom State, Nigeria. *Inter-Disciplinary Journal of Science Education*, 5(1), pp.11–25. Available from: https://ij-sed.com/3.6.%20Duru.pdf.

[6] Hammond, J., Garner, I., Hill, M., Patch, C., Hunter, A., Searle, B., Sanderson, S.C. and Lewis, C., 2021. Animation or leaflet: Does it make a difference when educating young people about genome sequencing? *Patient Education and Counseling*, 104(10), pp.2522–2530. Available from: https://doi.org/10.1016/j.pec.2021.02.048.

[7] Haseltine, W.A. and Patarca, R., 2024. The RNA Revolution in the Central Molecular Biology Dogma Evolution. *International Journal of Molecular Sciences*, 25(23), p.12695. Available from: https://doi.org/10.3390/ijms252312695.

[8] Kaushal, R.K. and Panda, S.N., 2019. A Meta Analysis on Effective conditions to Offer Animation Based Teaching Style. *Malaysian Journal of Learning and Instruction*, 16(1). Available from: https://doi.org/10.32890/mjli2019.16.1.6.

[9] Lewis, C., Sanderson, S.C., Hammond, J., Hill, M., Searle, B., Hunter, A., Patch, C. and Chitty, L.S., 2020. Development and mixed-methods evaluation of an online animation for young people about genome sequencing. *European Journal of Human Genetics*, 28(7), Jul, pp.896–906. Available from: https://doi.org/10.1038/s41431-019-0564-5.

[10] Mardis, E.R., 2017. DNA sequencing technologies: 2006–2016. *Nature Protocols*, 12(2), Feb, pp.213–218. Available from: https://doi.org/10.1038/nprot.2016.182.

[11] Ojo, A.T., 2024. Examination of secondary school students' conceptual understanding, perceptions, and misconceptions about genetics concepts. *Pedagogical Research*, 9(1), p.em0185. Available from: https://doi.org/10.29333/pr/14095.

[12] Omran, S., Leong, S.L., Blebil, A., Mohan, D. and Teoh, S.L., 2023. Effectiveness of pharmacogenomics educational interventions on healthcare professionals and health professions students: A systematic review. *Research in Social and Administrative Pharmacy*, 19(11), pp.1399–1411. Available from: https://doi.org/10.1016/j.sapharm.2023.07.012.

[13] Paivio, A., 1986. *Mental Representations: A dual coding approach Get access Arrow*. New York: Oxford University Press. Available from: https://doi.org/10.1093/acprof:oso/9780195066661.001.0001.

[14] Rajaram, K., 2021. Learning Interventions: Collaborative Learning, Critical Thinking and Assessing Participation Real-Time. *Evidence-Based Teaching for the 21st Century Classroom and Beyond: Innovation-Driven Learning Strategies*. Singapore: Springer Singapore, pp.77–120. Available from: https://doi.org/10.1007/978-981-33-6804-0_3.

[15] Rini, C., Henderson, G.E., Evans, J.P., Berg, J.S., Foreman, A.K.M., Griesemer, I., Waltz, M., O'Daniel, J.M. and Roche, M.I., 2020. Genomic knowledge in the context of diagnostic exome sequencing: changes over time, persistent subgroup differences, and associations with psychological sequencing outcomes. *Genetics in Medicine*, 22(1), pp.60–68. Available from: https://doi.org/10.1038/s41436-019-0600-4.

[16] Rogers, H.B., Orado, G.N. and Nasibi, M., 2023. Computer 3D Animation Use and Its Effect on Secondary School Students' Conceptual Understanding of Mammalian Circulatory System in Kiambu County, Kenya. *International Journal of Research and Innovation in Social Science*, 7(7), pp.986–993. https://www.researchgate.net/publication/374532987, Available from: https://doi.org/10.47772/IJRISS.2023.70776.

[17] Saira, Zafar, N. and Hafeez, M., 2021. A Critical Review on Discussion and Traditional Teaching Methods. *Psychology and Education*, 58(1), pp.1871–1886. Available from: https://doi.org/10.17762/pae.v58i1.1042.

[18] Satam, H., Joshi, K., Mangrolia, U., Waghoo, S., Zaidi, G., Rawool, S., Thakare, R.P., Banday, S., Mishra, A.K., Das, G. and Malonia, S.K., 2023. Next-Generation Sequencing Technology: Current Trends and Advancements. *Biology*, 12(7), p.997. Available from: https://doi.org/10.3390/biology12070997.

[19] Sweller, J., 1988. Cognitive Load During Problem Solving: Effects on Learning. *Cognitive Science*, 12(2), pp.257–285. Available from: https://doi.org/10.1207/s15516709cog1202_4.

[20] Teplá, M., Teplý, P. and Šmejkal, P., 2022. Influence of 3D models and animations on students in natural subjects. *International Journal of STEM Education*, 9(1), Oct, p.65. Available from: https://doi.org/10.1186/s40594-022-00382-8.

[21] Urry, L.A., Cain, M.L., Wasserman, S.A., Minorsky, P.V. and Orr, R.B., 2021. *Campbell Biology*. 12th ed. Pearson.

[22] Vygotsky, L.S., 1978. *Mind in Society: Development of Higher Psychological Processes*. Harvard University Press. Available from: https://w.pauldowling.me/rtf/2021.1/readings/LSVygotsky_

1978_MindinSocietyDevelopmentofHigherPsycholo.pdf.

[23] Williams, W.R., 2020. Examining Studio Ghibli's Animated Films: A Study of Students' Viewing Paths and Creative Projects. *Journal of Adolescent & Adult Literacy*, 63(6), pp.639–650. Available from: https://doi.org/10.1002/jaal.1043.

[24] Zakariyah, A.F., Alamri, S.A., Alzahrani, M.M., Alamri, A.A., Khan, M.A. and Hanbazazh, M.A., 2024. Identifying knowledge deficiencies in genetics education among medical students and interns in Saudi Arabia- A cross-sectional study. *BMC Medical Education*, 24(1), Jul, p.778. Available from: https://doi.org/10.1186/s12909-024-05782-8.