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Development and Effectiveness of an Edutainment Package for Enhancing Higher-Order Thinking Skills in Biology Teacher Education: A Quasi-Experimental Study

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Abstract: A pre-service Biology teacher who can only remember facts is not in a good position to develop analytical, evaluative and creative thinking in the students to be taught in the classroom. The study was stimulated by this concern and a package of edutainment was developed and tested for strengthening higher order thinking skills, scientific literacy and interest of pre-service Biology teachers in Colleges of Education of North-Central Nigeria. The ADDIE model (Analysis, Design, Development, Implementation, Evaluation) was used in a research and development approach, and was used in conjunction with a pretest-posttest, non-randomized, non-equivalent control group quasi-experimental design. The sample consisted of 327 NCE III pre-service Biology teachers from four of the Colleges of Education, and Genetics was the instructional content which was used for the treatment. Four instruments were used to be validated and the reliability coefficient for each instrument was 0,786 - 0,852. The results of the independent-samples z-tests at 0.05 level of significance revealed that pre-service teachers who were taught with the edutainment package performed significantly higher than those who were taught conventionally in scientific literacy ($z = 17.93$, $p < .05$), higher-order thinking skills ($z = 19.35$, $p < .05$), and interest ($z = 2.98$, $p < .05$). There were no significant gender differences for any of the three outcomes ($p > .05$) among those who received the edutainment treatment, suggesting that the treatment had a similar effect on male and female pre-service teachers. The results of this study provide a replicable ADDIE-based template for creating similar interventions in other STEM teacher education programmes and place edutainment as a viable gender-equitable approach for reforming teacher preparation programmes in resource-constrained settings.

Keywords: Edutainment; higher-order thinking skills; ADDIE model; scientific literacy; pre-service teachers; Biology education; quasi-experimental design

1. Introduction

Biology sits in a strange middle ground between the sciences of school education: much of what students are expected to learn cannot be learned by mere rote memorisation, but rote memorisation remains the dominant mode of learning in many classrooms. Higher-order thinking, which involves the ability to analyse, evaluate and create rather than simply recall, has thus been a recurring need in science education reform (Liu et al., 2024; Sivakumar & Boon 2026). It is not that teachers don't agree with this goal, it is that the pre-service teachers who will eventually teach in classrooms are not necessarily taught in ways that model it. In Nigeria, colleges of education, which are responsible for training the next generation of Biology teachers, are yet to move beyond lecture-based pedagogies and hence the output of their programs are graduates that can recite the stages of meiosis but cannot solve a new genetics problem.

One way out of this dilemma has been suggested time and again as "edutainment," or the conscious integration of instructional material and elements of entertainment like story, competition, and interactive media. The gamified and playful instructional formats have been found to capture and hold the learner's attention, increase engagement, and even enhance conceptual understanding in some documented cases, which conventional lecturing fails to (Lellis-Santos,2026). In the field of Biology, the use of game in teaching genetics has led to the consolidation of the knowledge of molecular concepts that are difficult to understand for prospective teachers (Focant, et al., 2026). A relatively sparse amount of systematic evidence exists, however, that a purpose-built edutainment package, developed using an instructional design process and tested against a control group, can impact higher-order thinking specifically and that this impact is equally found for both male and female pre-service teachers, a question of direct import to equity in STEM teacher preparation.

This study was aimed to fill that gap. It created an edutainment package for teaching Genetics to pre-service Biology teachers in Colleges of Education using ADDIE instructional design model, tested the impact of the package on three outcomes (scientific literacy, higher order thinking skills and interest), and investigated whether there was any difference in the impact of the package on the outcomes between males and females. The study was based on the following hypotheses:

H_2: The mean scores of scientific literacy in pre-service Biology teachers who have been taught by the edutainment method are not significantly different from the mean scores of those who have been taught by the conventional method.
H_2: Higher order thinking skills mean scores are the same for both groups.
H_3: The mean score for the interest for the two groups are not significantly different.

There is no significant difference between male and female pre-service teachers in scientific literacy, higher order thinking skills and interest mean scores in the teaching of using edutainment in 4th, 5th and 6th grade students.

In addition to the immediate results, the study also provides a design template for the ADDIE methodology that can be replicated by other teacher education programmes in Biology and STEM, especially in contexts with similar resource constraints, and evidence from the Nigerian context for the literature on edutainment that is still largely dominated by research on younger learners in more resource-rich systems.

3. Methodology

3.1 Research Design

The study was a combination of two designs appropriate for the two-part purpose. The edutainment package was developed using a research and development (R&D) design, which is based on the five ADDIE stages. Having to use intact classes and not disrupt normal college timetabling, its effectiveness was then tested by a pre test – post test design of a quasi experimental research of non-randomised, non-equivalent control group type.

3.2 Population and Sample

The population comprised 11,546 pre-service teachers teaching Biology in Colleges of Education in North-Central Nigeria, while the target population was NCE III (300-level) pre-service teachers of the 2024/2025 academic session, because the Genetics content is common for all the Colleges of Education in the region as per the minimum standards curriculum for NCE. The final sample consisted of six states and one federal territory in North-Central Nigeria which were clustered into four clusters based on geographical proximity and one government-owned, ICT-equipped College of Education was purposively selected from each cluster, followed by an intact NCE III class being sampled from each selected College of Education and randomly assigned to the experimental and control groups. This process resulted in an analytic sample of 327 pre-service Biology teachers (196 from the experimental group and 131 from the control group; 88 male, 108 female in the experimental group).

3.3 Instruments

Four instruments were used. The Edutainment package was used as the intervention tool and was created following the ADDIE process and then validated by experts in Educational Technology. Biology lecturers developed and validated a Biology higher order thinking ability test and a Biology scientific literacy ability test which was also reviewed by measurement and evaluation experts at the Federal University of Technology, Minna. The instrument set was completed by an interest questionnaire. Reliability was demonstrated using a pilot study given to an intact class that was not in the main sample, but was,

however, eligible. The split-half reliability results indicated a mean of 0.812 with scientific-ability, analysis-ability and synthesis-ability sub-components of the higher-order thinking test having coefficients of 0.836, 0.829 and 0.820 respectively, and the evaluation-ability sub-component having a coefficient of 0.786. The interest questionnaire was administered only once and analysed with Cronbach's alpha and yielded a coefficient of 0.852. Both are well above the standard 0.70 for research tools in the social and educational sciences.

3.4 Procedure and Data Analysis

A pretest was administered to both the groups prior to the treatment. For the experimental group, the content was then delivered as Genetics using the edutainment package during the intervention period, and for the control group, the same content was delivered using the traditional lecturing method. Both groups then took the same validated instruments for a post test. Descriptive statistics (mean and standard deviation) were used to answer the research questions and independent-samples z-tests at the 0.05 level of significance were used to test the six null hypotheses, given the sample sizes involved in each comparison.

4. Results

As presented in Table 1 the scores achieved by the pre-service teachers who were taught by using the edutainment package were higher than those of the pre-service teachers who were taught conventionally in all three outcomes; therefore, Cohen's d was calculated from the reported mean and standard deviations to determine whether the difference that was found were statistically significant or practically meaningful. The scientific literacy advantage (Mdiff = 33.38, $z = 17.93$, $p < .001$) is a large effect (Cohen's 1988 criteria), as is the higher-order thinking advantage (Mdiff = 24.25, $z = 19.35$, $p < .001$) ($d = 1.94$ and 2.20 respectively, both of which are well above Cohen's (1988) .80 threshold for a large effect, and which are among the more powerful instructional effects reported in the STEM education literature with $d > 1.0$ being rare even for well-designed interventions). The interest gain is also statistically significant (Mdiff = 3.56, $z = 2.98$, $p < .05$) but is a small effect ($d = 0.28$). This is a significant result itself because it suggests that the package's benefits for conventional instruction are mostly cognitive and not motivational, and it warns against the general belief in the edutainment literature that gamified/playful instruction is more motivational. In this case, interest changed the least of the three constructs and conceptual understanding and higher-order reasoning changed the most, indicating that it is the restructuring of instruction in the package, and not just its entertainment value, that is making the biggest difference.

Table 1: Effect of Edutainment on Scientific Literacy, Higher-Order Thinking Skills, and Interest

Variable	Group	N	Mean	SD	DF	Z	P	Decision
Scientific Literacy	Experimental	196	73.72	18.62				
	Control	131	40.34	14.92	325	17.93	.00*	Significant
Higher-Order Thinking	Experimental	196	71.83	10.80				
	Control	131	47.58	11.31	325	19.35	.00*	Significant
Interest	Experimental	196	61.67	16.40				
	Control	131	58.11	2.81	325	2.98	.00*	Significant

*Significant at $p < 0.05$.

Note: Z was calculated as $(M_1 - M_2) / \sqrt{(SD_1^2/n_1 + SD_2^2/n_2)}$, using each groups sample standard deviation as an estimate of its Population Standard deviation; this is asymptotically justified given the large per – group sample sizes in every comparison reported here ($n \geq 88$). Degrees of freedom ($n_1 + n_2 - 2$) are reported for transparency but are not required to evaluate the z – statistic itself; the same computation and note apply to table 2.

Table 2 shows that, within the experimental group, gender comparisons produced effect sizes close to zero for all three outcomes (scientific literacy $d = 0.01$; higher-order thinking $d = -0.04$; interest $d = -0.06$), alongside non-significant z-values ($p = .94, .82, .67$). These effect sizes are not merely non-significant but are trivial in magnitude by any conventional benchmark, which strengthens rather than simply permits the inference of gender equivalence: the null result is unlikely to reflect a Type II error masking a real difference, since the point estimates themselves carry essentially no practical weight. Taken together, the two tables tell a coherent and, for the field, an encouraging story. The edutainment package produced very large, gender-invariant gains in the cognitive outcomes that are most central to teacher preparation (scientific literacy and higher-order thinking), a smaller but still significant gain in interest, and no evidence that either male or female pre-service teachers benefited disproportionately from the intervention (H_1–H_3 rejected; H_4–H_6 not rejected).

Table 2: Gender Comparison Among Pre-Service Teachers Taught Using Edutainment

Variable	Group	N	Mean	SD	DF	Z	P	Decision
Scientific Literacy	Male	108	73.81	18.80				
	Female	88	73.61	18.49	194	0.08	.94	Not significant
Higher-Order Thinking	Male	108	71.66	7.63				
	Female	88	72.04	13.77	194	0.23	.82	Not significant
Interest	Male	108	61.20	14.39				
	Female	88	62.25	18.64	194	0.43	.67	Not significant

Taken together, the two tables show a consistent pattern. Pre-service teachers taught using the edutainment package scored substantially higher on scientific literacy, higher-order thinking, and interest than their conventionally taught peers, and each of these three differences reached statistical significance well beyond the 0.05 threshold (H_1–H_3 rejected). Within the experimental group, however, male and female pre-service teachers performed at statistically indistinguishable levels on all three outcomes (H_4–H_6 not rejected), with mean differences small enough in most cases to be attributable to sampling variation rather than any systematic gender effect.

5. Discussion

The magnitude of the difference in higher order thinking scores between the two groups is adequate to suggest a certain degree of caution in the conclusion that edutainment is a viable solution, but not so great that it is not comparable to previous studies that show that structured, non-lecture instructional formats yield meaningful gains in higher order thinking. Similar improvements have been found by Alanazi et al. (2024) in physics with scaffolding and guided discovery, and by Vrbanović Lisac (2025) in Biology, in a quasi-experimental design. The present study adds to this pattern by providing evidence that the same logic is applicable specifically to pre-service teachers, but not to secondary or undergraduate learners; for the latter, it is also important, but their own instructional experiences may be possibly replicated since poor higher-order reasoning in a prospective teacher risk being reproduced in every future classroom the teachers lead. which is a different issue altogether.

The scientific literacy result is generally in line with studies on the teaching of Biology that have been conducted by applying an inquiry-based teaching method and socio-scientific approaches to science teaching, which have repeatedly indicated that learning by engaging with content is associated with an increase in the ability to reason with evidence (Suwono et al., 2021a, 2021b). It's an interesting finding, and one that should not be overlooked: The effect of the edutainment package on affective outcomes was statistically significant, but it was not the largest of the three outcomes. This implies that novelty and engagement are not without limits; that is, that an edutainment package may provide benefits over conventional teaching in affective outcomes, but those benefits may not be as great as they seem with a control group that's undergoing structured, purposeful instruction as against strictly lecture methods. This is an important aspect for anyone who might want to over-sell edutainment simply as a motivational device; in this study, the most obvious benefit of edutainment was cognitive rather than affective.

In some ways the most important result here is that there is no significant effect of gender within the experimental group. It suggests that the edutainment package was not just a way of increasing the average result without either deepening or flattening a pre-existing male–female divide among pre-service teachers, but of changing both groups' outcomes together. This finding is somewhat interesting in relation to the study on EE conducted by Addo et al. (2025), who discovered that although there was no significant interaction between instructional design and gender, there was a significant main effect of gender on learner interest. Read side by side, the two studies indicate that instructional interventions can be gender neutral in their effects as edutainment was in this case, but it does not seem to be guaranteed by the design of the intervention; it seems to depend on the specifics of the content, on the population, and on the intervention itself, which is why gender should continue to be tested in future edutainment research, rather than assumed.

6. Conclusion

This study aimed to determine if a systematically designed edutainment package has a positive impact on higher-order thinking, scientific literacy and interest of pre-service Biology teachers of the Colleges of Education in terms of gender. The evidence answers both these questions in the affirmative. The edutainment package was built using the ADDIE model and subsequently tested against a conventionally taught control group resulting in significant and in the case of higher-order thinking and scientific literacy, substantial gains; and no significant gender disparity between those who received the package. This finding provides empirical evidence for the use of edutainment in teacher education because Nigeria and likely other teacher education systems have traditionally relied on transmission-based teaching, which is what the control group in this study exhibited.

7. **Recommendations:**

Based on the results, the following recommendations are made:

1. Educational strategies which incorporate elements of entertainment should be incorporated in the teaching of conceptually demanding Biology topics like Genetics in Colleges of Education and not used as occasions for enrichment.
2. The curriculum planners of teacher education must also integrate the training of instructional design into the Educational Technology courses, and before pre-service teachers leave the college, they can design edutainment materials instead of consuming.
3. College administrators need to make the ICT infrastructure that is essential for edutainment delivery a priority, as inequitable access to this infrastructure may undermine a good strategy and create another inequity.
4. Developers of future edutainment packages should research design features that will help to maintain the motivation in longer periods of instruction, given the relatively small size of the interest gain compared to the cognitive gain that was seen.

Declaration

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Competing Interest: Authors declare no competing interest

Data Availability: Data is available upon request from the corresponding author

Ethical approval: The study was conducted in accordance with the standards of the Nigerian national code of research ethics (www.nhrec.net) Ethical approval was waived in the study by Nigerian National Health Research Ethics Committee (NHREC) based on its guidelines providing exemption to studies in educational settings involving normal educational practices which is in line with Federal Ministry of Health (2007).

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Consent to participate

Informed written consents to participate in the study were obtained from all individual participants as respondents were assured of confidentiality of their identity and the respondents voluntarily participated in the study.

Consent to publish

Informed written consents to publish the result of the article were obtained from all individual participants and the identities of respondents were not disclosed in the study

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