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Differentiated Enriched Modelling Instruction: Investigating Gender Influences and Motivation in Environmental Concepts among Upper Basic Science Students in Zaria, Kaduna State, Nigeria

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Abstract

Environmental concepts in Basic Science and Technology remain among the most challenging topics for upper basic students in Nigeria, partly due to continued reliance on conventional, teacher-centred instruction. This study investigated the effect of Differentiated Enriched Modelling Instruction (DEMI) on the motivation of upper basic III students toward environmental concepts in Zaria Education Zone, Kaduna State, Nigeria, and whether the effect differed by gender. A pretest–posttest, non-randomised quasi-experimental design was adopted, involving 187 students (102 males, 85 females) from two intact classes in two public junior secondary schools, of whom 178 completed both pretest and posttest. Two schools were first selected through simple random sampling; the intact classes were then randomly assigned to experimental and control conditions using the draw-from-the-hat method. Data were collected using the Basic Science and Technology Motivation Questionnaire (reliability = .89). The experimental group was taught using DEMI for six weeks, while the control group received conventional instruction. Data were analysed using mean ranks and the Mann–Whitney U test at $\alpha \leq .05$. Findings showed a significant difference in motivation favouring students taught with DEMI, $U = 1157.10$, $z = 8.62$, $p < .001$, $r = .65$. However, no significant gender influence on motivation was found within the group taught using DEMI, $U = 822.50$, $z = -0.82$, $p = .411$, $r = .09$. The study concludes that DEMI is an effective instruction for enhancing students' motivation in environmental concepts and that, within the treatment group, its motivational benefit did not differ significantly between males and females. The study recommends the adoption of DEMI, which can be implemented with locally available instructional materials keywords differentiated instruction, modelling, motivation, environmental concepts, basic science, gender, Kaduna state.

Keywords: differentiated instruction, modelling, motivation, environmental concepts, basic science, gender, Kaduna state

1 Introduction

The importance of science to national development cannot be overemphasised, as science and technology are widely regarded as the driving force for global development in the twenty-first century (National Research Council [NRC], 2012). Science touches virtually every sphere of life, including critical thinking, problem-solving, technological innovation, health care, climate-change awareness and disaster preparedness (Osborne, Simon, & Collins, 2003). Effective science teaching from the basic education level, alongside an understanding of students' learning styles, is therefore essential for building public awareness of science and improving the standard of science teaching in Nigerian schools. The National Policy on Science and Technology Education (Federal Ministry of Education [FME], 2018) identifies science and technology education as a prerequisite for a knowledge-based economy and innovation. However, the policy also laments the absence of a robust framework that hinders Nigeria's technological take-off and contributes to students' poor achievement in Science, Technology, Engineering and Mathematics (STEM), partly attributable to students' poor motivation toward learning Basic Science and Technology.

Basic Science and Technology (BST), an interdisciplinary subject that unifies the various science disciplines into a single entity, forms the basis for every core science subject offered at the senior secondary level (Oguezue et al., 2023; Mbonu-Adigwe et al., 2021). Despite its importance, students continue to face challenges in the subject, with environmental concepts identified among the most difficult topics for upper basic students (Adamu, 2021; Abubakar, 2025). Empirical evidence suggests that one major contributing factor to students' difficulties in BST is teachers' continued reliance on conventional methods of instruction that neglect students' individual learning styles (Adamu, 2021). Consequently, researchers have advocated for innovative, student-centred and hands-on strategies such as Differentiated Instruction (DI)

to promote meaningful learning in BST (Al-Shehri, 2020; Nwachukwu et al., 2020). Enriching Differentiated Instruction with modelling blends the strategy to supplement and enhance lessons, tailoring instruction to individual students' learning styles while illustrating abstract environmental phenomena through models, with the potential to enhance students' motivation.

Motivation, described as the force that energises and directs behaviour toward goals (Deci & Ryan, 2000), has long been identified as a critical factor in effective learning; its absence is one of the most frustrating obstacles to students' learning (Ryan & Deci, 2000). Gender differences in science motivation also remain a contested issue, with some studies reporting no significant influence between male and female students while others reported disparities (Delahunty et al., 2025). Although several studies have examined the effect of either Differentiated Instruction or modelling on students' learning outcomes, relatively few have investigated their combined effect on upper basic students' motivation in environmental concepts, particularly within the Nigerian context; evidence of the combined strategy's influence on gender equally remains limited. The present study addressed this gap by investigating the effect of Differentiated Enriched Modelling Instruction (DEMI) on upper basic students' motivation and gender influence toward environmental concepts in Zaria Education Zone, Kaduna State, Nigeria. Specifically, it addressed the following research questions:

1. What is the difference between the motivations of upper basic students taught environmental concepts using DEMI and those taught using the conventional method?
2. What is the difference in the motivation of male and female upper basic students taught environmental concepts using DEMI?

Answers to these questions provide useful evidence for Basic Science teachers and curriculum developers seeking to enhance students' motivation toward learning environmentally relevant scientific concepts irrespective of gender.

2 Literature Review and Theoretical Framework

This study is anchored on Bandura's Social Learning Theory (Bandura, 1977) and Self-Determination Theory (Deci & Ryan, 1985). Bandura's Social Learning Theory posits that learners acquire new behaviours and understanding by observing and imitating models, providing a suitable theoretical basis for modelling instruction, in which learners construct an understanding of abstract phenomena such as environmental hazards, through observation of physical or visual representations. Self-Determination Theory complements this perspective by explaining that learners' motivation is enhanced when their needs for autonomy, competence and relatedness are met. Differentiated Instruction, which tailors content, process and product to individual learners' needs and learning styles (Tomlinson, 2001), addresses these needs by giving students choice and flexibility in how they learn, thereby promoting the kind of intrinsic motivation explained by Self-Determination Theory. Together, these theories provide the conceptual basis for explaining how Differentiated Instruction enriched with Modelling (DEMI) may enhance students' motivation toward learning environmental concepts.

2.1 Basic Science and Technology and Environmental Concepts

Basic Science and Technology is an interdisciplinary subject that attempts to remove the boundaries between the various single science subjects by presenting science as one entity through a unified approach (Oguezue et al., 2023). Mbonu-Adigwe et al. (2021) further posited that Basic Science is the foundation for every core science subject offered by students at the senior secondary level. Environmental concepts, according to Miller and Spoolman (2018), encompass the study of the natural world and the interactions between human activities and Earth's physical, chemical and biological systems, aiming to address problems like pollution, resource depletion and climate change. The Nigerian Educational Research and Development Council (NERDC, 2012) stated that environmental concepts focus on understanding the components of the biophysical environment, natural resources and environmental hazards such as soil erosion, flooding, deforestation and ozone depletion to promote sustainable living and environmental protection. Given their relevance to everyday life and sustainable development, environmental-hazards concepts constitute an important and challenging component of the Basic Science and Technology curriculum at the upper basic level.

2.2 Differentiated Instructional Strategy

Differentiated Instruction, according to Tomlinson (2001), is a process of tailoring lessons to meet each student's individual interests, needs and strengths. Tomlinson further explained that teaching through a differentiated approach gives students

choice and flexibility in how they learn and helps teachers personalise learning and is therefore most suitable in learning environments that incorporate students with different learning styles. Content, process and product constitute the backbone of differentiation, with the learning environment frequently added as a fourth element acknowledging the role that physical space plays in learning (Tomlinson, 2001). Several empirical studies have examined the effect of Differentiated Instruction on students' learning. For instance, Musa and Hassan (2022) found that a differentiated instructional strategy improves students' motivation towards learning.

2.3 Modelling Instruction

Modelling instruction engages learners in the construction, validation and application of conceptual models of phenomena that may be too small, too large or too complex to observe directly (Wells, et al 1995). The use of models in the classroom can help teachers improve their explanations; rather than simply explaining a concept verbally from the front of the classroom, it is more effective for a teacher to refer to a visual or physical model while giving explanations (Wells et al., 1995). Akhiruddin et al. (2024) found that a modelling strategy improves students' motivation, while Davronova (2025) recommended the use of modelling instruction to enhance students' meaningful learning in Basic Science. The present study used modelling in enriching Differentiated Instruction to teach environmental-hazards concepts and its effect on students' motivation was observed. Differentiated Enriched Modelling Instruction (DEMI) is therefore a teaching strategy that blends differentiated and modelling instruction to supplement, enhance and make lessons more attractive to meet individual students' needs based on learning styles, with the potential to motivate students toward learning environmental concepts.

2.4 Motivation in Science Learning

Motivation, according to Deci and Ryan (2000), is the force that energises and directs behaviour; learners who are motivated pursue goals and persist in the face of challenges. Ryan and Deci (2000) observed that a lack of motivation has long been one of the most frustrating obstacles to students' learning. However, the use of innovative instruction has been found to enhance students' motivation toward science regardless of gender.

2.5 Gender and Motivation in Science Learning

Gender, according to the World Health Organization (WHO, 2025), refers to the characteristics of women, men, girls and boys that are socially constructed. Gender stereotyping in Science, Technology, Engineering and Mathematics has long been a concern among researchers. For instance, Delahunty et al. (2025) opined that the underrepresentation of females in STEM education and careers is a global issue, occurring in part due to the pervasive gender stereotypes often associated with STEM fields. A number of studies have examined modelling instruction in relation to gender. Kamaruddin et al. (2021) found that male students were more motivated toward science learning than female students. In contrast, Muhammed (2024) found that male and female students did not differ significantly in their motivation toward science learning, although female students were found to be slightly better motivated than their male counterparts. Gender therefore remains a controversial factor in the academic setting that warrants further empirical investigation, which was the gap filled by the present study.

3 Materials and Methods

3.1 Research Design, Population, Sample and Sampling Technique

The study employed a pretest–posttest, non-randomised quasi-experimental design with experimental and control groups. The study population comprised 7,379 upper basic III students (3,732 males; 3,647 females) in all twenty-six (26) junior secondary schools in Zaria Education Zone. A cluster sampling procedure was used. The primary sampling units were the schools: two co-educational public schools were first selected from the 26 schools through simple random sampling. Within the selected schools, one intact upper basic III class in each school was then randomly assigned to either the experimental (DEMI) or the control (conventional instruction) condition using the draw-from-the-hat method. Individual students were not randomly assigned; intact classes were used to avoid disrupting normal school programmes. The resulting sample consisted of 187 students (102 males, 85 females) at pretest. All 187 sampled students completed the pretest; however, 178 completed the posttest (experimental group: 92 at pretest, 87 at posttest; control group: 95 at pretest, 91 at posttest), giving

an overall attrition rate of 4.8% (experimental 4.5%; control 4.2%). The nine students who did not complete the posttest were those absent on the day of posttest administration and those who had withdrawn from school during the intervention period. Because attrition was below 5% in each group and approximately balanced across groups and also because pretest equivalence of the completer groups was confirmed (see Table 2), the threat to internal validity from differential attrition is judged to be minimal. Nevertheless, all posttest analyses were conducted on the 178 students who completed the test.

3.2 Instrumentation

The instrument used for data collection was the Basic Science and Technology Motivation Questionnaire (BSTMQ), which was validated and subjected to Cronbach's alpha statistic, yielding a reliability coefficient of 0.89. A pilot study was carried out with the experimental group (taught using DEMI) to identify and categorise students according to their learning styles; this was achieved through the VARK student interview as recommended by Fleming and Mills (1992). Upper basic III intact classes were used for the study, comprising one experimental and one control group. A pretest (O1) was administered to both groups to establish their equivalence in terms of motivation. The experimental group (X1) was taught environmental concepts using DEMI, while the control group was taught same concepts using the conventional method for a six-week period. After the treatment, a posttest (O2) was administered to determine the effect of DEMI on students' motivation toward environmental concepts.

3.3 Data Analysis

Data were collated and analysed using the Statistical Package for Social Sciences (SPSS), version 26. Mean ranks were used to answer the research questions, while the null hypotheses were tested using the Mann–Whitney U test at $\alpha \leq .05$. The Mann–Whitney U test is the conventional non-parametric test for comparing two independent groups; for a two-group comparison it is algebraically equivalent to the Kruskal–Wallis H test (Kruskal–Wallis H with df = 1 equals the square of the Mann–Whitney z). The test statistic U, the normal-approximation z, the exact/asymptotic p-value, and the effect size r ($r = |z|/\sqrt{N}$) are reported for each comparison.

4 Results

4.1 Research Question One

What is the difference between the motivation scores of upper basic science students taught environmental concepts using DEMI and those taught using the conventional method?

The descriptive statistic of mean ranks was used to answer research question one. A summary of the result is presented in Table 1.

Table **1**

Pretest and Posttest Motivation Mean Ranks for Experimental and Control Groups

Test	**Group**	***N***	**Mean Rank**	Mean Rank Difference (Exp. − Con.)
Pretest	Experimental	92	93.51	-0.96
Pretest	Control	95	94.47	
Pretest	Total	187	—	
Posttest	Experimental	87	121.70	+66.56
Posttest	Control	91	55.14	
Posttest	Total	178	—	

Table 1 indicates that the pretest computed motivation mean ranks are 93.51 and 94.47 for the experimental and control groups respectively, a negligible difference of −0.96 in favour of the control group. The posttest computed motivation mean ranks are 121.70 and 55.14 for the experimental and control groups respectively, a difference of +66.56 in favour of the experimental group. This shows that a marked difference exists between the motivation scores of upper basic III students

taught environmental concepts using DEMI and their counterparts taught using the conventional method. Further analysis was conducted to ascertain the significance of the mean difference, leading to the testing of null hypothesis one.

4.2 Hypothesis One

$H0_1$: There is no significant difference between the motivation of upper basic students taught environmental concepts using DEMI and those taught using the conventional method.

This hypothesis was tested by subjecting the pretest and posttest motivation scores of both groups to the Mann–Whitney U test, presented in Table 2.

Table **2**

Mann-Whitney U Test of Pretest and Posttest Motivation Scores for Experimental and Control Groups

Test	**Group**	***N***	**Mean Rank**	**U**	**Z**	**P**	Remark	**Remark**
Pretest	Experimental	92	93.51	4324.92	−0.12	.901	N.Sig	
Pretest	Control	95	94.47					
Pretest	Total	187	—					.
Posttest	Experimental	87	121.70	1157.10	8.62	<.001	Sig.	
Posttest	Control	91	55.14					
Posttest	Total	178	—					

Note. Significant at $p < .05$. Effect sizes: pretest $r = .01$; posttest $r = .65$. The sign of z reflects the direction of the experimental minus control comparison.

Table 2 indicates that the pretest motivation mean ranks are 93.51 and 94.47 for the experimental and control groups respectively, with $U = 4324.92$, $z = −0.12$, and $p = .901$, which is greater than the alpha value of .05. This indicates that there was no significant difference between the pretest motivation scores of the experimental and control groups; the groups were equivalent at baseline. The posttest motivation mean ranks are 121.70 and 55.14 for the experimental and control groups respectively, with $U = 1157.10$, $z = 8.62$, and $p < .001$, which is less than the alpha value of .05, with a large effect size ($r = .65$). This shows that a significant difference exists between the motivation scores of upper basic students taught environmental concepts using DEMI and their counterparts taught using the conventional method, in favour of the DEMI group. This implies that DEMI had a strong positive effect on students' motivation toward learning environmental concepts, leading to the rejection of null hypothesis one.

4.3 Research Question Two

What is the difference in the motivation of male and female upper basic science students taught environmental concepts using DEMI?

The descriptive statistic of mean ranks was used to answer the question, as presented in Table 3.

Table **3**

Pretest and Posttest Motivation Mean Ranks across Gender in the Experimental Group

Test	**Gender**	***N***	**Mean Rank**	Mean Rank Difference (Male − Female
Pretest	Male	52	51.79	+12.16
Pretest	Female	40	39.63	
Pretest	Total	92	-	
Posttest	Male	48	44.50	−4.60
Posttest	Female	39	49.10	
Posttest	Total	87	-	

Table 3 shows that the pretest computed motivation mean rank scores for male and female students in the experimental group are 51.79 and 39.63 respectively, a difference of +12.16 in favour of males. The posttest computed motivation mean rank scores are 44.50 and 49.10 respectively, a difference of −4.60, with females now slightly higher. This shows that the initial male advantage in motivation was not only erased but slightly reversed after the DEMI intervention. Further analysis was conducted to ascertain the significance of these differences, leading to the testing of null hypothesis two.

4.4 Hypothesis Two

$H0_2$: There is no significant difference in the motivation of male and female upper basic students taught environmental-hazards concepts using DEMI.

The hypothesis was tested by subjecting the pretest and posttest motivation scores of male and female students in the experimental group to the Mann–Whitney U test, as presented in Table 4.

Table **4**

Mann-Whitney U Test of Pretest and Posttest Motivation Scores across Gender in the Experimental Group

Test	**Gender**	***N***	**Mean Rank**	**U**	**Z**	**P**	**Remark**
Pretest	Male	52	51.79	764.92	2.19	.029	Sig.
Pretest	Female	40	39.63				
Pretest	Total	92	-				
Posttest	Male	48	44.50	822.50	−0.82	.411	N.Sig.
Posttest	Female	39	49.10				
Posttest	Total	87	-				

Note. Significant at $p < .05$. Effect sizes: pretest $r = .23$; posttest $r = .09$. The sign of z reflects the direction of the male minus female comparison.

Table 4 shows that the pretest motivation mean rank scores for male and female students in the experimental group are 51.79 and 39.63 respectively, with U = 764.92, z = 2.19, and p = .029; thus a significant difference existed in motivation at pretest, in favour of male students. The posttest motivation mean rank scores are 44.50 and 49.10 respectively, with U = 822.50, z = −0.82, and p = .411; thus no significant difference existed at posttest. This implies that, within the group taught using DEMI, males and female did not differ significantly in motivation after treatment and the null hypothesis is not rejected. This conclusion is based on within-treatment-group comparisons only; a treatment-by-gender interaction against the control group was not tested.

5 Discussion

The result in Table 2 shows a significant difference between the motivation scores of students taught environmental concepts using DEMI and those taught the same concepts using the conventional method. This finding is supported by that of Salazar and Gumanoy (2025), who found differentiated instruction to be effective at improving students' motivation in mathematics education in the Philippines. Similarly, Lin et al. (2021), in a study on modelling the structural relationships among primary students' motivation to learn artificial intelligence in Beijing, China, found that intrinsic motivation had the strongest influence on career motivation, alongside the motivational strategies of attention, relevance and confidence. The present study's finding of a significant difference between the motivation of students taught environmental concepts using DEMI and those taught using the conventional method is therefore supported by previous studies emphasising the positive effects of differentiated and modelling instruction on students' motivation toward learning.

Result in Table 4 shows no significant difference in the posttest motivation scores of male and female students taught environmental concepts using DEMI. This finding agrees with that of Muhammed (2024), who reported no significant difference between male and female students' motivation toward science learning in Pakistan. Contrary to these findings, Kamaruddin et al. (2021) found that male students were more motivated than their female counterparts in Malaysia. This contradiction may be attributed to differences in geographical location, students' education level and the specific subjects and concepts taught in the respective studies. On balance, the present study's finding that DEMI produced no significant

gender influence in motivation is supported by studies emphasising the gender-inclusive benefits of differentiated and modelling instruction on students' motivation toward learning.

An important caveat accompanies the gender finding, however. At pretest, males in the DEMI group were significantly more motivated than females ($U = 764.92$, $p = .029$), a difference that was no longer significant at posttest ($U = 822.50$, $p = .411$), at which point females' mean rank slightly exceeded males'. Two interpretations are therefore possible. First, DEMI may be genuinely gender-fair, raising the motivation of the initially lower-motivated group (females) to the level of males. Second, the disappearance of a significant baseline difference may partly reflect regression to the mean, since significant group differences at baseline tend to shrink on re-measurement even without intervention. In support of the first interpretation, the posttest difference was not merely non-significant but slightly reversed in favour of females and DEMI's overall motivational effect was large ($r = .65$). Nevertheless, because no control-group gender comparison or treatment-by-gender interaction test was conducted and because gain scores could not be computed from the available ranked summaries.

The study acknowledged some limitations. First, the use of intact classes rather than individual random assignment of students may have introduced pre-existing group differences that could not be fully controlled for. Second, the study was restricted to two public junior secondary schools within Zaria Education Zone, which limits the generalisability of findings to other education zones or states. Third, the six-week duration of the DEMI intervention may not fully capture its longer-term effect on students' motivation. Fourth, motivation was assessed using a single self-report instrument, the Basic Science and Technology Motivation Questionnaire, which, although valid and reliable, may not capture all dimensions of students' motivation. Fifth, although attrition between pretest and posttest was low (about 5%) and approximately balanced across groups, unmeasured differences between completers and non-completers cannot be fully ruled out. Finally, a significant gender difference existed at pretest within the experimental group and the absence of a control-group gender comparison means that the gender-fair interpretation of the posttest result rests on within-group evidence only.

Future studies should consider employing longer intervention periods and multi-zone or multi-state samples to strengthen the generalisability of findings on DEMI. Researchers may also explore the effect of DEMI on other learning outcomes, such as academic performance and retention and adopt mixed-methods designs that incorporate qualitative exploration of students' experiences with differentiated and modelling instruction across other Basic Science and Technology concepts. In addition, future studies should include a control-group gender comparison and use ANCOVA or gain-score analyses with pretest motivation as a covariate, so that treatment-by-gender interactions can be tested directly.

6 Conclusion

We conclude that enriching Differentiated Instruction with modelling was effective in improving upper basic III students' motivation toward learning environmental concepts and that, within the treatment group, this effect was consistent for both male and female students. By integrating differentiation and modelling, teachers can create engaging and effective instructional practices that enhance students' motivation toward learning Basic Science and Technology. We therefore recommend that the teaching of environmental concepts be carried out by Basic Science teachers using DEMI, which promotes teacher-student interaction and accommodates each student's learning preference within the classroom. As implemented in this study, DEMI relied on modest, locally available instructional materials, including teacher-prepared models and visual charts. Where technology-enhanced versions of DEMI are adopted, school management in collaboration with the state Ministry of Education, should provide the instructional facilities needed for its effective and accessible implementation.

7 Declarations

Ethical Statements: The study involved upper basic III (JSS III) students, the majority of whom were minors. Approval to conduct the study was obtained from the Zaria Quality Assurance authority and the principals of the participating schools prior to data collection. Written informed consent was obtained from the parents/guardians of participating students and assent was obtained directly from the students themselves before their participation. Participants and their parents/guardians were informed of the study's purpose, the voluntary nature of participation and their right to withdraw at any stage without penalty. Confidentiality of participants' identities and responses was maintained throughout the study.

Conflict of Interest: The authors declare neither financial nor non-financial conflict of interest.

Author Contributions: SSM conceptualised the study, designed and implemented the DEMI intervention, collected the data and drafted the manuscript. AA contributed to the study design, supervised the data analysis, and critically reviewed and revised the manuscript for important intellectual content. Both authors read and approved the final manuscript and agree to be accountable for its content.

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