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Enhancing Creativity of Undergraduate Pre-Service Biology Teachers in Developing Cytology Instructional Materials through Stem Activity in Sokoto State, Nigeria

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ABSTRACT

Cytology Instructional Materials through STEM activities in Sokoto State, Nigeria' with the objectives to find the difference and examine the creativity of pre-service biology teachers, also males and females exposed to STEM activities and those exposed to teacher-centered demonstration method in developing cytology instructional materials, had two research questions and research hypotheses each, which were answered and tested respectively. The study adopted pre-test- post-test quasi-experimental design. The population comprises of 1,054 (300) level pre-service biology teachers from three selected Universities and one College of Education. A total of 206 sampled participants were drawn using purposive, simple random and multistage sampling from two Universities (UDUS & SSU) and were assigned to STEM and Teacher Centered teaching method groups. Quantitative data were collected using the Cytology Creativity Assessment Guide (CCAG). The instrument was validated by experts and was reliable by obtaining the reliability index of 0.98 using PPMC. Data were analyzed using mean and independent sample t-test and the results revealed a significant difference in creativity scores between pre-service biology teachers exposed to STEM activities and those taught using teacher centered demonstration method of teaching; with the STEM group recording higher creativity scores. Gender had no significant influence on creativity outcomes. The study recommended the integration of structured STEM modules, practical workshops and institutional support in Teacher Education programmes to improve biology teaching effectiveness and creativity.

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KEYWORDS:
Creativity, Pre-service Biology Teachers, Cytology Instructional Materials, STEM Activities

1. Introduction

Creativity is widely acknowledged as a core skill for success in the 21st century and across Educational system globally. Creativity has been positioned as fundamental to innovation,

problem-solving and the ability to adapt to complex, uncertain environments (Robinson, 2011). In science education, creativity plays a significant role in allowing learners and teachers to connect abstract concepts with innovative instructional practice (Runco & Jaeger, 2012). Scholars argue that science instruction that cultivates creativity encourages learners to generate multiple solutions, engage in inquiry and design novel artifacts, thereby deepening conceptual understanding (Cropley, 2016). In Nigerian Educational context, creativity has been repeatedly emphasized in national policy documents as a critical outcome of science education (Federal Republic of Nigeria, 2014). The National Policy on Education identifies the development of creative and innovative abilities as a primary goal of science and technical education. However, studies focusing on science teacher preparation in Nigeria have revealed a gap between this policy aspiration and classroom practice. Many Nigerian pre-servicer teachers for instance, often rely on textbooks-based instruction and teacher-centered methods that fail to nurture creative thinking or inventive practice (Aina & Akintunde, 2013; Yusuf & Afolabi, 2015).

Creativity is globally recognized and locally prescribed in Education policies. However, their actual objectives during teacher training remain limited in Sokoto State Teacher Education programmes. Therefore, the integration of STEM activity to explore pedagogical strategies that could easily develop pre-service teacher's creative competences in instructional material design becomes pertinent. Instructional materials are essential tools used to facilitate teaching and enhance learners understanding of concepts. These teaching tools include physical models, charts, laboratory apparatus, simulations, multimedia resources and improvised teaching aids that make abstract ideas concrete and accessible (Heinich, molenda, Russel, & Smaldino, 2018). In science education particularly, instructional materials serve as cognitive bridges between theoretical knowledge and observable phenomena (Bruner, 2011). Recent educational reforms emphasize that teachers should not only use ready-made materials but also possess the creative competence to design and develop context-appropriate instructional materials (UNESCO, 2017). The shift toward constructivist and inquiry-based learning models has reinforced the importance of hands-on, student-centered instructional tools that encourage exploration and experimentation (Bybee, 2013). However, in Nigeria, the importance of instructional materials has been consistently highlighted in the National Policy on Education (Federal Republic of Nigeria, 2013), which emphasizes the use of relevant teaching aids to enhance science instruction. However, despite policy advocacy, studies reveal that instructional materials are either inadequate or underutilized in many Nigerian schools and Teacher Education institutions (Aina, 2013).

Cytology is a required topic in the senior secondary school biology curriculum in Nigeria and examined by National Examinations Council. Furthermore, in Sokoto State, the teaching and learning of cytology may be further constrained by limited laboratory facilities and overcrowded classrooms. This leads to overreliance on theoretical instruction and consequently, pre-service biology teachers trained within this context may have limited opportunities to engage in practical with cytology concepts during their preparation, so without creative instructional strategies and STEM-based engagement, the abstract nature of cytology remains a barrier to effective learning. Given these challenges, there is a compelling need to explore innovative pedagogical approaches that can enhance pre-service teacher's creativity and capacity to design effective instructional materials for teaching cytology. Integrating STEM activities into teacher preparation may provide a practical pathway to improve both conceptual understanding and instructional competence in this critical area of biology.

Cytology, as a branch of biology is concerned with the study of cells. It constitutes a foundational component of biological sciences. Since the formulation of the cell theory by Schwann in the nineteenth century, the cell has been recognized as the basic structural and functional unit of life. In global view, cytology forms a core topic in secondary and tertiary biology curricula because it underpins understanding of genetics, physiology and molecular biology. Despite its importance, cytology is widely regarded as one of the most abstract and conceptually demanding area of biology. Research indicates that students often experience misconceptions regarding cell structure, organelle functions and processes such as mitosis and meiosis (Lewis & Wood-Robinson, 2010). Cells are microscopic and cannot be observed directly without specialized equipment, and require effective teaching visual models, laboratory investigations and interactive instructional materials. The OECD (2019) advocates inquiry-based science instruction to improve conceptual understanding of complex scientific phenomena, including cellular processes.

Science, Technology, Engineering and Mathematics (STEM) education has emerged globally as a transformative instructional approach designed to prepare learners with 21st century competencies, such as creativity, collaboration, critical thinking and problem-solving (Bybee, 2013). Rather than teaching science and mathematics as isolated subjects, STEM promotes interdisciplinary integration through real-world problem-solving and design-based learning experiences. STEM activities typically involve hands-on tasks such as engineering design challenges, model construction and simulation that require learners to apply scientific knowledge in practical contexts (Moore et al., 2014). Research indicates that such activities enhance creativity, innovation and conceptual understanding because learners actively construct knowledge rather than passively receive information (Kelly & Knowles, 2016), while Okorie and Eze (2019) observed that there is no significant improvement in creativity among science students exposed to poorly implemented STEM activities.

In Nigeria, several studies have emphasized on the teachers creativity in science education. Mbaegbu, Awosika, and Colleages (2020) who investigated Biology Teachers Creativity and Students' Academic Performance in Awka South, Anambra State, opined that teachers with higher creativity levels produced better-performing students. Akinbola (2015) examined the effectiveness of hands-on instructional strategies on students' performance and creativity in biology in Nigerian secondary schools and observed that students exposed to practical, activity-based learning performed better and demonstrated higher creative abilities. Ogunleye (2022) who opined that integrating STEM approaches in teaching cytology foster hands-on engagement, problem solving and innovation, which are crucial for developing creative teaching materials. Similarly, Adekunle (2021) on Enhanced Science Teachers Creative Skills in Ondo State, Nigeria using 'How creative are you test' revealed that teachers demonstrated only fair levels of creative thinking, with demographic variables exerting no significant effect. Okebukola (2010) investigated innovative teaching strategies in science education in Nigeria; on poor science performance among secondary and tertiary institutions and emphasized the need for learner-centered approaches to improve creativity and scientific thinking. Indicating that poor science performance was due to poor laboratories, low teacher quality and lack of practical teaching.

In a study on the impact of student-centered instructional strategies in secondary school Oyo Adesoji and Olatunbosun (2008) maintained that participatory learning improves understanding retention and academic achievement, while the present study focused specifically on creativity and instructional product development. Nworgu (2015) highlighted the importance of practical and inquiry-based science teaching in teacher education and maintained that

introducing innovative teaching will enhance student capability in their studies. Eze and Ezeugo (2020) found that biology teachers who engaged in innovative and creative instructional practices improved learners understanding of complex biological concepts. Umar (2017) examined the challenges of teaching biology in northern Nigerian Secondary Schools and revealed that lack of instructional materials, inadequate teacher preparation and limited practical exposure are key issues. While at the material improvisation level, Dave-Ugwu et al. (2025) explored creativity in the improvisation of chemistry instructional materials in Nsukka Zone, Enugu State revealed very low levels of creative improvisation, caused by inadequate resources and insufficient teacher training. Olatoye and Aremu (2021) and Yusuf (2019) reported that gender differences in science performance diminish when learners-centered and activity-based instructional strategies are used. This outcome could be attributed to the collaborative nature of STEM activities adopted in the study, where participants worked in mixed-gender groups and shared responsibilities during model construction. Suraj et al. (2021) found that STEM instruction minimized gender disparities by providing equal opportunities for participation and hands-on engagement.

In this study however on enhancing creativity of UG pre-service biology teachers in developing cytology instructional materials through STEM activity in Sokoto State, Nigeria preliminary investigation shows that the teaching and learning of cytology in Sokoto is not encouraging because teachers adopt the teacher centered method as a way of teaching and learning mainly because of inadequate teaching materials. However, Studies conducted in northern Nigerian universities often indicate that pre-service teachers often have minimal opportunities to engage in hands-on material construction activities during their training (Sadiq, Musa, & Lawal 2021). As a result, their ability to creatively develop instructional materials for abstract biology topics such as cytology remains underdeveloped. Abubakar and Umar (2022) observed that biology students in Sokoto experience difficulty understanding cell biology concepts partly because instructional materials are either unavailable or not innovatively designed. This suggests that enhancing pre-service teacher's competence in developing instructional materials could improve biology instruction in the State. This situation necessitates empirical investigation into strategies, such as STEM-based activities, that can enhance creativity and instructional material development among pre-service biology teachers in Sokoto State.

Research Questions

1. Is there any difference between the creativity of pre-service biology teachers exposed to STEM activities and those exposed to teacher centered demonstration method in developing cytology instructional materials for teaching?
2. Is there any difference between the creativity of male and female pre-service biology teachers exposed to STEM activities in developing cytology instructional materials for teaching?

Research Hypotheses

The following hypotheses were used:

$H0_1$: There is no significant difference between pre-service biology teachers' Creativity exposed to STEM Activity and those exposed to Teacher-centered demonstration method of teaching in developing cytology instructional materials for teaching.

$H0_2$: There is no significant difference between the male and female pre-service Biology teachers' Creativity in developing cytology instructional materials using STEM approach for teaching.

2. Methodology

The study adopted Pre-test and Post-test quasi-experimental designs. A quasi-experimental design offers a valuable approach for evaluating the effectiveness of interventions or programmes when random assignment is not feasible (Maciejewski, 2020). This design requires careful implementation to ensure valid and reliable results. It is appropriate because it requires comparison of groups to establish a baseline or control condition (Shadish, Cook & Campbell, 2019). In this study STEM Activity had been incorporated in teaching the experimental group while control group had been taught by Teacher-centered demonstration method of teaching. The experimental and control groups had been selected through intact class from the sampled Universities. The population of the study comprised of 1,054 (300L) pre-service biology teachers from four public higher institutions in Sokoto State: Usmanu Danfodiyo University Sokoto (UDUS), Shehu Shagari College of Education (Undergraduate affiliation programme), Sokoto State University (SSU), and Shehu Shagari University of Education (SSUE). Using purposive and multi-stage sampling techniques, the sample size of 206 pre-service biology teachers (which was slightly lower than the sample size of 291 recommended by the research advisor table) were selected. The use of purposive sampling method was acknowledge by Freankel and Wallen (2021) and supported by Renu Bisht (2024), who acknowledged the suitability of the method if the population is small with clear research purpose, allowing researchers to target individuals with specific attributes relevant to the study. In selecting the sample, multi-stage sampling was used to first select institutions, level of study and simple random sampling for the pre-service teachers. Purposive sampling was used to select the institution that met the following criteria:

1. Offer biology Education as a course
2. Have students at UG 300 level
3. Have both male and female pre-service biology teachers.

Based on the aforementioned criteria, the Shehu Shagari University of Education does not have 300 level pre-service biology teachers; and thus did not satisfy criteria number 2. Therefore, the study would not be conducted at that University. Two out of the three universities (Usmanu Dan Fodio University, Sokoto (UDUS) and Sokoto State University (SSU) satisfied all three criteria. The universities selected were believed to be a fair representation of the types of Universities that offer biology courses. However, data was collected using Cytology Creativity Enhancement Guide (CCEG) instrument which was used to score the respondents at a sitting developing plant and animal cell models through STEM Activity and through the conducted interviews for selected participants of pre-service biology teachers (male and female) who participated in STEM Activity using an interview guide. The instruments were validated by experts in the department of Science Education, Sokoto State University. All corrections and suggestions were duly incorporated. Pilot study was conducted on two instances of two weeks interval to ensure the instruments are measureable and a reliability index of 0.98 was arrived at. Descriptive statistic was used to analyze the STEM Activity creativity scores from both the experimental and control groups. The qualitative data were analyzed using thematic analysis.

3. Result

Research Question 1: Is there any difference between the creativity of pre-service biology teachers exposed to STEM activities and those exposed to teacher centered demonstration method in developing instructional materials for teaching cytology?

Table 1: Descriptive Statistics on UG Pre-service Biology Teachers' Creativity on Experimental Group and Control Group

Groups	N	$\bar{X}$	SD	Mean Diff
Experimental Group	100	52.80	6.713	
				21.4364
Control Group	106	31.36	6.830	

Table1 summarizes the descriptive statistics for pre-service biology teachers' creativity skills. Pre-service teachers taught with STEM strategy scored a mean of 52.80 and Standard Deviation (SD) =6.713 while those trained through demonstration have a mean of 31.36 and SD =6.830. The mean difference of 21.43 favors the experimental group taught using STEM strategy. This revealed that pre-service biology teachers participated in STEM activities (experimental group) shows higher Creativity in developing instructional materials for teaching cytology when compared to their counterparts in the control group.

Research Question 2: Is there any difference between the Creativity of male and female pre-service biology teachers exposed to STEM activities in developing instructional materials for teaching cytology?

Table 2: Descriptive Statistics of Male and Female Pre-service Biology Teachers' Creativity in STEM Activity

Strategy	Sex	N	$\bar{X}$	SD	Mean Diff
STEM Activity	Male	60	53.00	6.69328	0.50
	Female	40	52.50	7.76745	

Table 2 summarizes the descriptive statistics among male and female students creativity in STEM Activity. The male scored a Mean of 53.00 and Standard Deviation (SD) = 6.69 while, the female pre-service biology teachers have a Mean of 52.50 and SD = 7.76. This indicates a mean difference of 0.50 in favor of the male students. Therefore, this showed marginally small differences in the creativity to develop instructional materials for teaching cytology between male and female pre-service teachers trained through STEM Activities.

Testing of Null Hypotheses

T-test was employed to test the stated hypotheses 1 and 2 which stated the following:

Null Hypothesis 1 (HO_1): There is no significant difference between pre-service biology teachers' creativity exposed to STEM Activity and those exposed to Teacher-centered demonstration method strategies of teaching in developing instructional materials for teaching cytology. To analyze this hypothesis, the scores were subjected to independent sample t-test analysis. The result of the analysis is shown in table 3.

Table 3: Summary of t-test Analysis of the Difference between Pre-service Biology Teachers' Creativity in Experimental and Control Group

Groups	N	$\bar{X}$	SD	Df	t-Cal	P-Value	Decision
STEM Activity	100	52.80	6.71				
				204	7.24	.000	**H_{01}** Rejected
Teacher-centered demonstration method	106	31.36	6.83				

$\alpha \leq 0.05$ level of significance

Table 3 shows that the calculated t-value was t (204) = 7.24, and a P-value of .000 which is less than the ≤ 0.05 ($p=0.000< 0.05$) level of significance at degree of freedom of 204, (df = 204). This indicate a statistically significant difference between the creativity scores of pre-service biology teachers taught using STEM activities and those taught using the Teacher-centered demonstration method. Based on this result, the null hypothesis one (Ho_1) was rejected. This implies that exposure to STEM activities had a significant positive effect on the Creativity of pre-servicer biology teachers in developing instructional materials for teaching cytology. The higher mean score obtained by the STEM group suggests that STEM-based instruction is more effective in fostering Creativity than the Teacher-centered demonstration method teaching.

Null hypothesis 2 (HO_2): There is no significant difference between the male and female pre-service Biology teachers' creativity in developing instructional materials using STEM approach for teaching cytology.

Table 4: Summary of t-test Analysis of the Difference between Male and Female Pre-service Biology Teachers' Creativity in Developing Instructional Material through STEM Activity

Strategy	Sex	N	$\bar{X}$	SD	df	t-Cal	P-Value	Decision
STEM Activity	Male	60	53.00	6.693				
					98	0.109	0.916	**H_{O2}** Accepted
	Female	40	52.50	7.767				

$\alpha \leq 0.05$ level of significance

Table 4 shows that the calculated t-value was = 0.109, and a P-value of 0.916 which is greater than the ≤ 0.05 ($p=0.916< 0.05$) level of significance at degree of freedom of 98, (df= 98). This indicate that there is no statistically significant difference between the creativity scores of male pre-service biology teachers and female pre-service biology teachers taught using STEM activities. Based on this result, the null hypothesis (Ho_1) was accepted. This implies that exposure to STEM activities

had equal significant positive effect on both the creativity of male and female pre-service biology teachers when equally guided in developing instructional materials for teaching cytology. The mean score obtained by both male and female suggest that STEM-based instruction and development of instructional materials for teaching cytology has no gender biased creativity skills.

4. Discussions of the Findings

The study examined how to enhance the creativity of pre-service undergraduates biology teachers' exposed to STEM Activities and those exposed to conventional method of teaching in developing instructional materials for teaching cytology in Sokoto State, Nigeria. The study revealed that pre-service biology teachers exposed to STEM-based activity demonstrated significant higher creativity scores than those taught with conventional methods. This is in line with the findings of Ogunleye (2022) who opined that integrating STEM approaches in teaching cytology foster hands-on engagement, problem solving and innovation, which are crucial for developing creative teaching materials.

The finding of this study indicated that pre-service biology teachers exposed to STEM activities demonstrated higher creativity in developing instructional materials for teaching cytology than those taught using conventional teaching strategies. The independent sample t-test showed a statistically significant difference in creativity scores in favor of Experimental group, which lead to the rejection of null hypothesis. This finding aligns directly with the objective one of the study, which sought to determine the effect of STEM activities on creativity and answers research question one.

The result suggests that STEM-based instructional approaches, which emphasize on hands-on activities, collaboration, problem-solving, and model construction, provide richer learning experiences that stimulate creative thinking among pre-service teachers. This supports the constructivist learning theory, which posits that learners actively construct knowledge through meaningful engagement with tasks and materials. Through engaging pre-service teachers in group-based construction of cytology models using locally available materials, STEM activities encouraged originality, flexibility, and innovation which are core components of creativity. This finding is consistent with earlier studies which reported that STEM-based instruction enhances creativity and higher order thinking skills among science learners and teachers (Ogunleye & Adebimpe, (2022); Yusuf & Adigun, 2021). Similarly, Eze and Ezeugo (2020) found that biology teachers who engaged in innovative and creative instructional practices improved learners understanding of complex biological concepts. Furthermore, Oluruntegbe and Adebayo (2020) reported that STEM activities enhance creativity and problem-solving abilities among science teacher trainees in southwestern Nigeria.

A study found to be supportive on international standard by Yuliani and lee (2020) also observed that integrated STEM learning promotes creativity by linking science concepts with real-life application. However, Okorie and Eze (2019) finding contradicts this study who found there was no significant improvement in creativity among science students exposed to poorly implemented STEM activities. The difference may be attributed to the structured nature of the STEM intervention and the use of a creativity assessment guide (CCAG) in the present study.

The finding of this study further indicated that there was no gender difference in the creativity scores of male and female pre-service biology teachers exposed to STEM activities. This indicated that STEM activities enhanced creativity of both gender. This finding aligns with objective tow of the study and addresses research question two, which examined the influence of gender on creativity when STEM activities are employed. The result suggests that when provided

with equal learning opportunities and supportive instructional environments, both male and female pre-service teachers can develop creativity at comparable levels.

The findings of Olatoye and Aremu (2021) and Yusuf (2019) reported that gender differences in science performance diminish when learners-centered and activity-based instructional strategies are used. This outcome could be attributed to the collaborative nature of STEM activities adopted in the study, where participants worked in mixed-gender groups and shared responsibilities during model construction. Such collaborative learning environments reduce gender bias and promote equal participation. Little more Abdul-talib et al. (2020) reported no significant gender difference in creative thinking skills among science students taught using activity-based methods in Nigerian college of education. Similarly, Suraj et al. (2021) found that STEM instruction minimized gender disparities by providing equal opportunities for participation and hands-on engagement. However, a study of Onah and Ugwu (2019), contradicts the present study who reported that male students performed better in STEM-related creative tasks due to higher exposure to technical activities. The contradiction may be because of the contextual differences, as the present study deliberately used collaborative group work and locally improvised materials, which may reduce gender-based participation barriers particularly in Sokoto context.

5. Conclusion

In conclusion, the study was carried to examine how to enhance the creativity of UG pre-service biology teachers when integrating STEM activities in developing cytology instructional materials through STEM activity in Sokoto State, Nigeria. Based on the quantitative findings of this study, it indicates that pre-service biology teachers' who are exposed to STEM activity showed more creativity than those exposed to conventional strategies or teacher-centered method of teaching. Similarly, the STEM Strategy approach is gender friendly, because it enhances the creativity of both male and female pre-service biology teachers' in developing instructional materials for teaching cytology, without significant differences. Therefore, it can be concluded that integrating STEM-activities module in learning strategy in the teaching of cytology concepts is a better option to enhance pre-service biology teachers' creativity at universities in Sokoto State, Nigeria.

6. Recommendations

The following recommendations are provided

1. Teacher Education institutions should adopt STEM activities in practical courses to enhance creativity of pre-service teachers in biology class
2. Biology educators should design STEM activities that ensure equal participation, leadership roles and Enhancement opportunities for all pre-service teachers, regardless of gender, to maintain equity in Creativity development.

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