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Effect of Modelling Clay on The Performance of Field-Dependent and Field-Independent Senior School Students in Cell Division

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Abstrak

Pembelahan sel telah diidentifikasi dalam literatur sebagai proses biologi yang sulit dipelajari karena strategi instruksional yang buruk dan ketidakmampuan siswa untuk menggambarkan antara mitosis dan meiosis. Oleh karena itu, perlu dicari strategi alternatif seperti pemodelan tanah liat untuk konkretisasi proses pembelahan sel. Oleh karena itu, penelitian ini dilaksanakan untuk menganalisis efek dari pemodelan tanah liat pada kinerja siswa sekolah menengah yang bergantung pada lapangan dan mandiri dalam pembelahan sel. Penelitian ini merupakan penelitian eksperimen. Data dikumpulkan dengan menggunakan observasi, adopsi dan tes yang dirancang peneliti. Teknik kualitatif dan kuantitatif digunakan untuk analisis data. Subyek penelitian ini adalah pemodelan tanah liat yang digunakan oleh 97 siswa kelas utuh untuk pembelajaran pembelahan sel. Temuan menunjukkan bahwa tidak ada perbedaan yang signifikan dalam kinerja siswa yang bergantung pada bidang dan yang tidak bergantung pada bidang. Juga, tidak ada interaksi antara perlakuan dan gaya kognitif siswa. Oleh karena itu, disimpulkan bahwa pemodelan tanah liat memfasilitasi siswa belajar pembelahan sel terlepas dari gaya kognitif. Implikasi pedagogisnya adalah bahwa pemodelan tanah liat dapat meningkatkan pemahaman siswa tentang proses kehidupan yang terjadi di dalam sel dan dengan perluasan proses biologis lainnya.

***Kata kunci**: Pemodelan Tanah Liat, Tergantung bidang, Lapangan-independen, Pertunjukan, Pembelahan sel*

Abstract

Cell division has been identified in literature as a hard-to-learn biology process due to poor instructional strategies and students' inability to delineate between mitosis and meiosis. Hence, there is need to explore alternative strategy such as modelling clay for the concretization of cell division processes. Therefore, this study, conducted to analyse the effects of modelling clay on the performance of field-dependent and field-independent senior school students in cell division. The study is experimental research. Data was collected using observations, adopted and researchers designed tests. Qualitative and quantitative techniques were used for data analysis. The research subject was modelling clay used by 97 intact class students for learning cell division. The findings revealed that there was no significant difference in the performance of field-dependent and field-independent students. Also, there was no interaction between treatment and students' cognitive styles. Therefore, it was concluded that modelling clay facilitated students learning of cell division irrespective of cognitive styles. The pedagogical implication is that modelling clay can enhance students' understanding of the life processes taking place in the cell and by extension other biological processes.

Keywords: Modelling Clay, Field-dependent, Field-independent, Performance, Cell Division

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1. INTRODUCTION

Biology as a pure science subject deals with the study of living things in relation to their evolution, taxonomy, functions and behavior (Alwan, 2011; Ferreira & Morais, 2020). The importance of biology cannot be overemphasized in understanding human health, behavior, and environment. Furthermore, biology serves as an important perquisite for students that intend to pursue future career in related courses such as pharmacy, medicine, biochemistry, microbiology, zoology, and botany (Okwara et al., 2017; Taştan et al., 2018). Despite the laudable importance of biology to human, several researchers have observed that the performance of senior school students in biology is unimpressive (Bichi et al., 2019; Owoeye, P. O., & Agbaje, 2016).

Among the various factors and causal variables identified for the unimpressive performances of students in biology are the lack of mass (Abe et al., 2019; Adeoye & Abimbola, 2016), inadequate or absence of instructional materials (Agada & Sam-Kayode, 2022; Ibrahim et al., 2021), and the difficulty of some biology topics, processes and concepts (Elangovan, 2018; Frederick-Jonah & Tobi, 2022). For instance, cell division, a topical content in the Nigerian Senior Secondary School biology curriculum has been identified by researchers as a hard-to-teach and hard-to-learn concept for both senior school teachers and students respectively (Badmus et al., 2019; de Graaf et al., 2019). Due to the instructional strategy used by teachers to aid learners' visualization and construction of mental picture of the life processes taking place in the cell (Elangovan, 2018; Luwoye et al., 2021).

Based on the forgoing, one solution that can be administered to facilitate the construction of knowledge by students is the use of modelling clay which is a flexible and colorful material that comes in different colors and can be used for modelling things. Modelling clay is usually in different colors and forms such as, the natural earthy material (clay soil), play dough produced from flour, and plasticine which is an artificial clay material (Herur et al., 2011; Meganingtyas et al., 2019). Play dough was however, used in this study for concretizing and learning cell division processes because it is cost effective, it is not dirty and non-sticky, can be stored and re-used a number of times for classroom teaching and learning. Evidences abound in literature that the use of modelling clay enhanced the learning of veterinary anatomy and periventricular structure of the human brain (Akle et al., 2017; Onuk et al., 2019). In addition, modelling clay had a positive influence on students' performances when compared with video observations and real dissection procedure (DeHoff et al., 2011; Kooloos et al., 2014). Modelling clay was also used in the present study but unlike previous studies students created their own models through a small activity group with focus on students' cognitive styles.

The cognitive styles of learners (as field-dependent and field-independent individual) was considered in the present study because cognitive style is a potent variable in determining students' academic choices, vocational preferences, and how students processes knowledge (Marchetti & Cullen, 2015; Witkin, 1973). Field-dependent learners are non-analytic individuals' that process information using external references and succeed in situations where structures are provided as they actively engage their intuition and trial-and-error approaches to solving problems. Field-independent learners on the other hand are analytic individual who rely on internal references when solving their problem by perceiving objects as a whole thereby finding out the underlying causal relationships of problem situations (Idika, 2017; Kotob & Arnouss, 2019).

There are some previous studies have revealed that researchers held contradictory views on students' cognitive styles in relation to their performances. One of previous study observed that cognitive styles significantly mediated the relationship between motivation and students' performances in Biology (Saka & Onanuga, 2022). Other researcher also found out that cognitive styles significantly influenced students' performance (Shemy, 2021). Contrastingly, with that other researcher found out that the performance of students in biology was not influenced by cognitive styles (Okoye, 2016).

The teaching and learning of cell division in the absence of appropriate instructional strategies may affect the knowledge processing skills of field-dependent and field-independent students, thus, the need to explore student-centered strategies which may aid the construction of learner's idiosyncratic knowledge. The modelling clay may provide an answer in this regard because it can be easily manipulated as symbolic representation of the topics, concept or processes being studied. Based on the foregoing, the objectives of the present study were to analyses the difference in the performance of field-dependent and field-independent senior school students' that learnt cell division using modelling clay; and the interaction effect of treatment and cognitive style on the performance of senior school students' in cell division.

2. METHODS

This type of research is quasi-experimental research of the non-randomized, pre-test, post-test control group design. The approach was used due to the in ability of the researchers to randomly assigned the participants into the experimental and control groups (Gopalan et al., 2020; Miller et al., 2020). The population for the study consisted of all Senior Secondary Schools students offering biology in Omu-Aran, Kwara State, Nigeria while the target population was composed of Senior Secondary School two (SSS II) students. The sample comprised of an intact class of 97 (52 field-dependent and 45 field-dependent). Senior Secondary School two biology students selected from two senior secondary schools using purposive sampling technique. Purposive sampling technique was considered appropriate because the schools must not be situated close to each other, have at least one biology teacher teaching Senior Secondary School two students, and the willingness of the relevant members of staff and students to participate in the study.

The instruments used for data collection in this study were Cell Division Performance Test (CDPT) and Group Embedded Figure Test (GEFT) while modelling clay and Research Assistant Training Guide (RATG) constituted the stimulus instruments. The Modelling clay used in this study was playdough prepared using flour, baking powder, water, vegetable oil, food colouring agents and food preservatives. The RATG was used as a guide to train the Research Assistants while GEFT was a non-verbal paper base test (Johnes et al., 2017; Witkin et al., 1971). The CDPT was a researcher-designed test instrument which consisted of fifty-seven multiple choice test items on cell division. Each of the questions had four options A-D and was used to assess students' performance in cell division. (Anderson et al., 2001; Krathwohl, 2002).

On the procedure for the research, the CDPT was subjected to item analysis while three biology education experts from a University and two experienced senior secondary school biology teachers determined the face and content validity of the GEFT and CDPT. The reliability of the GEFT and CDPT were determined using the test-retest procedure and Pearson product-moment correlation statistic. The experiment lasted for five weeks in each of the selected schools. The schedule activities are show in Table 1.

Table 1. Weekly Schedule of Activities for Data Collection

Scheduled Activity	Period
Administration of GEFT and Training of Research Assistants	Week 1
Pre-test administration	Week 2
Treatment	Week 3-4
Post-test administration	Week 5

Data analysis was carried out using *t*-test and Analysis of Covariance (ANCOVA) at 0.05 level of significance. Ethical issues observed include anonymity, confidentiality and the health risks of using the modeling clay was avoided by using non-toxic play dough made from edible wheat flour.

3. RESULTS AND DISCUSSION

Results

In this study, the data collected using the Cell Division Performance Test (CDPT) were collated and analysed using *t*-test and Analysis of Covariance (ANCOVA). All statistical analyses were carried out at 0.05 level of significance using the Statistical Package for Social Science. *T*-test result of the performance of field-dependent and field-independent senior school students that learnt cell division using modeling clay is show in Table 2.

Table 2. *t*-test Result of the Performance of Field-Dependent and Field-Independent Senior School Students

Treatment	Cognitive Styles	N	*M*	*T*	*df*	Sig.
Modelling clay	Field-dependent Field-independent	27 24	28.96 29.92	-0.67	49	0.50

The independent sample *t*-test result in Table 2 revealed that the obtained *t*-value -0.67 with *p* value 0.50 was not significant, since the *p*-value was greater than 0.05 alpha levels. Thus, the null hypothesis, which states that there is no significant difference in the performance of field-dependent and field-independent senior school students' that learnt cell division using modelling clay, was not rejected $t(49) = -0.67$, $p = 0.50$. In addition, there was a marginal difference in the mean scores of the field-dependent ($M = 28.96$) and the field-independent students ($M = 29.92$) that learnt cell division using modelling clay. Then Anocova test result is show in Table 3.

Table 3. Summary of the ANCOVA of the Interaction Effect of Treatment and Cognitive Styles

Source	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.	η_p^2
Corrected Model	2308.517[a]	4	577.129	36.779	0.00	0.62
Intercept	934.529	1	934.529	59.555	0.00	0.39
Pretest	881.479	1	881.479	56.174	0.00	0.38
Treatment	1516.409	1	1516.409	96.637	0.00	0.51
Cognitive styles	66.376	1	66.376	4.230	0.04	0.04
Treatment * Cognitive styles	36.246	1	36.246	2.310	0.13	0.02
Error	1443.648	92	15.692			
Total	69793.000	97				
Corrected Total	3752.165	96				

Based on Table 3 show ANCOVA between treatment (modelling clay and conventional method) and cognitive styles (field dependent and field independent) in Table 3 revealed that the interaction between treatment and cognitive styles was not statistically significant, $F_{(1, 92)} = 2.31$, $p = .13$. Thus, the null hypothesis was not rejected since $p > 0.05$. Hence, there was no interaction effect between treatment and cognitive style on the performance of senior school students' that learnt cell division using modelling clay and those that learnt it with the conventional method. Profile plot showing the interaction effect of treatment and cognitive styles is show in Figure 1.

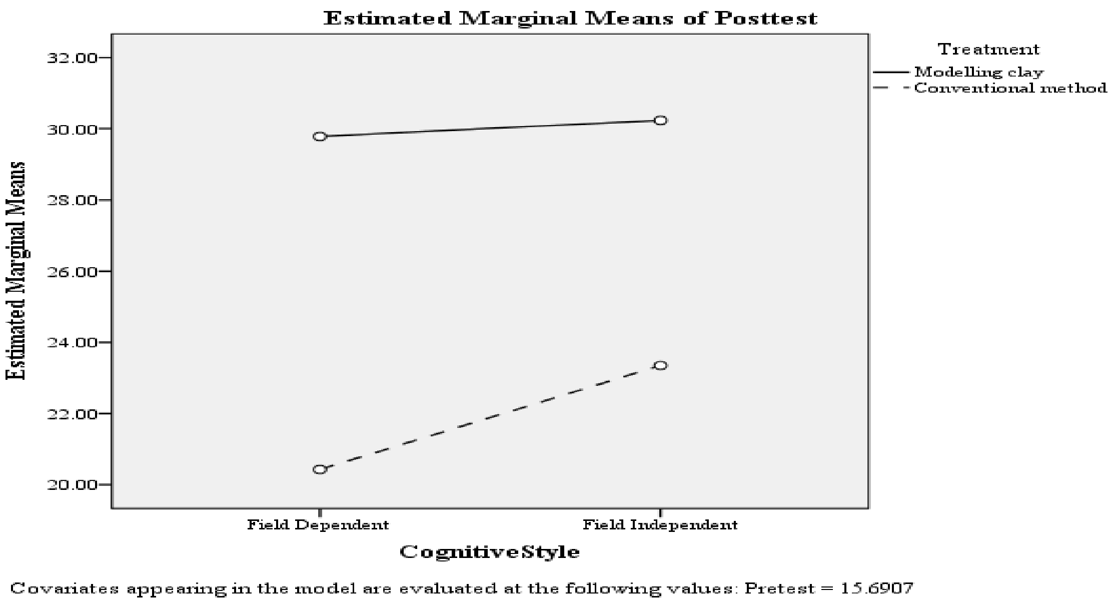

Figure 1. Profile Plot showing the interaction effect of treatment and cognitive styles

Figure 1 shows that the interaction between treatment and cognitive styles gave an ordinal interaction (parallel lines) and this suggest that the performances of the field-dependent and field-independent students were enhanced by the different forms of treatments used in the study but that of the experimental group that learnt cell division using modelling clay was more apparent.

Discussion

Teachers at all levels of education are saddled with the responsibility of implementing the curriculum and facilitating learning. However, without the right instructional aid the attainment of the objectives of teaching may not be successfully achieved (Okenyi, 2022; Olumorin et al., 2022). Previous studies have indicated that modelling clay is an effective teaching aid for facilitating learning through pedagogies that is based on cooperative approach (Grigg et al., 2020; Sanchez-Acevedo, M., & Kao, 2022). However, most existing literature did not consider the cognitive abilities of learners in consonance with their usage of modelling clay for knowledge construction. Thus, justifying the importance of the findings of the present study to the field of education and practice.

Based on the first hypothesis tested, it was discovered that there was no significant difference in the performance of field-dependent and field-independent senior school students' in cell division after exposure to the modelling clay. The result indicated that although, the effect of modelling clay was not significant. However, the effect was more apparent for the field-independent students who had a mean score of (M = 29.92) as compared to (M = 28.96) of the field-dependent students.

This finding contradicts the results of previous studies that significant difference existed in the performance of field-dependent and field-independent learners (Idika, 2017; Saka & Onanuga, 2022; Setiwan, A., Koderi, W., & Pratiwi, 2020). Similar research results showed that the cognitive styles of students did not significantly affect the performance of field-dependent and field-independent learners ((Sulaiman, M. M., & Bello, 2022). Previous studies and the result of the present study in Figure 2 indicated that playdough – a colourful and pliable clay material, facilitates learning (Herur et al., 2011). The pedagogical implication of the finding is that modelling clay enhanced students' performance irrespective of students' cognitive styles.

The second hypothesis tested in this study revealed that there was no interaction effect of treatment and cognitive styles on senior school students performance in cell division. This finding is not in conformity with previous studies which stated that the interaction effect of treatment and cognitive styles is significant (Ibrahem et al., 2022). However, the finding is in consonance with the findings of similar studies that the interaction effect of treatment and cognitive styles was not significance (Okoye, 2016; Singh & Dutt, 2022). With reference to related previous studies, the no interaction effect of treatment and cognitive style can be attributed to the modelling clay which facilitated students' knowledge construction irrespective of their cognitive styles (Marchetti & Cullen, 2015; Sanchez-Acevedo, M., & Kao, 2022). It can be generally concluded from the finding that teachers should place more credence on the cognitive characteristics of learners and use appropriate pedagogies and instructional aid to facilitate learning.

The impact of the study is that modeling clay can be used as a learning tool to facilitate students understanding and performance in cell division. Based on the findings the following recommendations were made that biology teachers and students should embrace the use of modeling clay for effective teaching and meaningful learning of cell division processes most especially if students are of different cognitive styles. In addition, active teaching can be used to complement the use of modeling clay during classroom teaching and learning. The limitation of this study is seen from the scope of the research which only analyzes the effect of modeling clay on the performance of high school students in cell division. It is hoped that further research will be able to analyze more deeply related to the use of clay modeling in learning.

4. CONCLUSION

This study, conducted to analyses the effects of modeling clay on the performance of field-dependent and field-independent senior school students' in cell division. The research involve in total 97 of students for learning cell division. The findings revealed that there was no significant difference in the performance of field-dependent and field-independent students. Also, there was no interaction between treatment and students' cognitive styles. Based on the research conducted, it can be concluded that modelling clay is effective for enhancing the performance of field-dependent and field-independent senior school students' in cell division.

5. REFERENCES

Abe, T. R., Bello, G., & Hamzat, A. (2019). Patterns of classroom interactions and students' reactions toward study barriers in biology lessons. *Lonaka Journal of Learning and Teaching*, *10*(1), 82–93. https://journals.ub.bw/index.php/jolt/article/download/1552/999.

Adeoye, G. A., & Abimbola, I. O. (2016). Effects of senior school students' use of demo kit on their achievement in biology in Omu-Aran, Nigeria. *Electronic Journal of Science Education*, *20*(8), 88–102. https://eric.ed.gov/?id=EJ1188100.

Agada, A., & Sam-Kayode, C. O. (2022). Effect of audio-visual materials on students' achievement in biological concepts in College of Education, Oyo. *International Journal of Social Science and Education Research Studies*, *2*(5), 138–142. https://doi.org/10.55677/ijssers/V02I05Y2022-06.

Akle, V., Peña-Silva, R. A., Valencia, D. M., & Rincón-Perez, C. W. (2017). Validation of clay modelling as a learning tool for the periventricular structures of the human brain. *Anatomical Science Education*, *1*(2), 137–145. https://doi.org/10.1002/ase.1719.

Alwan, A. A. (2011). Misconception of heat and temperature among physics students. *Procedia - Social and Behavioral Sciences*, *12*, 600–614. https://doi.org/10.1016/j.sbspro.2011.02.074.

Anderson, W., O., R., D., & Krathwohl. (2001). *A Taxonomy for Learning Teaching and Assessing*. Addison Wesley Longman Inc.

Badmus, T. S., Bello, G., Hamzat, A., & Sulaiman, M. M. (2019). Effects of WebQuest on secondary school biology students' achievement in cell division in Ilorin. *Humanities and Social Sciences Letters*, *7*(2), 64–73. https://doi.org/10.18488/journal.73.2019.72.64.73.

Bichi, A. A., Ibrahim, F. B., & Ibrahim, R. H. (2019). Assessment of students performances in biology: Implication for measurements and evaluation of learning. *Journal of Education and Learning*, *13*(3), 301–308. https://doi.org/10.11591/edulearn.v13i3.12200.

de Graaf, A., Westbroek, H., & Janssen, F. (2019). A practical approach to differentiated instruction: How Biology Teachers redesigned their genetics and ecology lessons. *Journal of Science Teacher Education*, *30*(1), 6–23. https://doi.org/10.1080/1046560X.2018.1523646.

DeHoff, M. E., Clark, K. L., & Meganathan, K. (2011). Learning outcomes and student perceived value of clay modelling and cat dissection in undergraduate human anatomy and physiology. *Advances in Physiology Education*, *35*(1), 68–75. https://doi.org/10.1152/advan.00094.2010.

Elangovan, T. (2018). Cartoonic and non-cartoonic simulations in reducing biology students' misconceptions in cell division. *International Journal of Academic Research in Business and Social Sciences*, *8*(4), 962–975. https://doi.org/10.6007 /IJARBSS/v8-i4/4237.

Ferreira, S., & Morais, A. M. (2020). Practical Work in Science Education: Study of Different Contexts of Pedagogic Practice. *Research in Science Education*, *50*(4). https://doi.org/10.1007/s11165-018-9743-6.

Frederick-Jonah, T. M., & Tobi, T. (2022). Areas and causes of students' difficulties in learning the concept of cell in secondary school biology curriculum. *International Journal of Advanced Academic Research*, *8*(3), 16–27. https://doi.org/10.46654 /articles/v8n3/ahe/ijaar-v8n3-Mar22-p8322.

Gopalan, M., Rosinger, K., & Ahn, J. Bin. (2020). Use of Quasi-Experimental Research Designs in Education Research: Growth, Promise, and Challenges. *Review of Research in Education*, *44*(1), 218–243. https://doi.org/10.3102/0091732X20903302.

Grigg, E. K., Hart, L. A., & Moffett, J. (2020). Comparison of the effects of clay modelling & cat cadaver dissection on high school students' outcomes & attitudes in a human anatomy course. *The American Biology Teacher*, *82*(9), 596–605. https://doi.org/10.1525/abt.2020.82.9.596.

Herur, A., Kolagi, S., Chinagudi, S., Manjula, R., & Patil, S. (2011). Active learning by playdough modelling in the medical profession. *Advances in Physiology Education*, *35*(2), 241–243. https://doi.org/10.1152/advan.00087.2010.

Ibrahem, U. M., Alsaif, B. S., Alblaihed, M., Ahmed, S. S. I., Alshrif, H. A., Abdulkader, R. A., & Diab, H. M. (2022). Interaction between cognitive styles and genders when using virtual laboratories and its influence on students of health college's laboratory skills and cognitive load during the Corona pandemic. *Heliyon*, *8*(4), 1–8. https://doi.org/10.1016/j.heliyon.2022.e09213.

Ibrahim, N., Mohammed, A. A., Abdullahi M., Uzoma, G. I., & Bizi, M. G. (2021). The attitude of biology teachers towards improvisation and utilization of instructional materials in teaching and learning biology in private secondary schools in Potiskum local government area. *GSC Advanced Research and Reviews*, *8*(1), 28–40. https://doi.org/10.30574/gscarr.2021.8.1.0112.

Idika, M. I. (2017). Influence of cognitive style and gender on secondary school students' achievement in and attitude to chemistry. *Advances in Social Sciences Research Journal*, *4*(1), 129–139. https://doi.org/10.14738/assrj.41.2585.

Johnes, J., Portela, M., & Thanassoulis, E. (2017). Efficiency in education. *Journal of the Operational Research Society*, *68*(4), 331–338. https://doi.org/10.1057/s41274-016-0109-z.

Kooloos, G. M., Schepens-Franke, A., Bergman, E. M., Donders, R., & Vorstenbosch, M. (2014). Anatomical knowledge gain through a clay-modelling exercise compared to live and video observations. *Anatomical Sciences Education*, *7*(6), 1–11. https://doi.org/10.1002/ase.1443.

Kotob, M., & Arnouss, D. (2019). Differentiated instruction: The effect on learner's achievement in Kindergarten. *International Journal of Contemporary Education*, *2*(2), 61. https://doi.org/10.11114/ijce.v2i2.4479.

Krathwohl, D. R. (2002). A revision of bloom's taxonomy: an overview. *Theory into Practice*, *41*(4), 212–218. https://doi.org/10.1207/s15430421tip4104_2.

Luwoye, A., Bello, G., & Adeoye, G. A. (2021). Influence of the demo kit on remediating senior school students' misconceptions in mitosis and meiosis in Ilorin, Nigeria. *Journal of Learning for Development*, *8*(3), 557–567. https://files.eric.ed.gov/fulltext /EJ1325029.pdf .

Marchetti, L., & Cullen, P. (2015). A Multimodal Approach in the Classroom for Creative Learning and Teaching. *Psychological and Creative Approaches to Language Teaching*, 39–51. https://doi.org/10.1016/j.bbalip.2011.04.004.

Meganingtyas, B. R., Winarni, R., & Murwaningsih, T. (2019). The Effect of Using Course Review Horay and Talking Stick Learning Methods Towards Social Science Learning Result Reviewed From Learning Interest. *International Journal of Educational Research Review*, *4*(2), 190–197. https://doi.org/10.24331/ijere.518053.

Miller, C. J., Smith, S. N., & Pugatch, M. (2020). Experimental and quasi-experimental designs in implementation research. *Psychiatry Research*, *283*. https://doi.org/10.1016/j.psychres.2019.06.027.

Okenyi, E. C. (2022). Impact of instructional materials on pupils' academic achievement in social studies in Enugu State, Nigeria. *Contemporary Journal of Education and Development*, *2*(6), 1–9. https://www.cirdjournal.com/index.php/cjed/article/download/749/691 .

Okoye, P. O. (2016). Influence of gender and cognitive styles on students' achievement in biology. *International Journal of Science and Technology*, *5*(1), 59–65. https://doi.org/10.4314/stech .v5i1.6.

Okwara, O. K., Anyagh, P. I., & Ikyaan, G. S. (2017). Effect of projected instructional media on senior secondary school students' achievement in biology. *International Journal of Scientific Research in Education*, *10*(2), 137–147. https://www.rsisinternational.org/journals/ijriss/Digital-Library /volume-3-issue-10/253-257.pdf.

Olumorin, C. O., Babalola, E. O., & Ayoola, D. A. (2022). Design and development of human excretory system model to teach a biology concept in Ilorin, Nigeria. *Indonesian Journal of Teaching in Science*, *2*(2), 107–111. https://ejournal.upi.edu/index.php/IJoTis /article/download/45782/18964.

Onuk, B., Çolak, A., Arslan, S., Sizer, S. S., & Kabak, M. (2019). The effects of clay modelling and plastic model dressing techniques on veterinary anatomy training. *Kafkas Univ Vet Fak Derg*, *25*(4), 545–551. https://doi.org/10.9775/kvfd.2018.21304.

Owoeye, P. O., & Agbaje, R. O. (2016). Students' attitude and gender as correlates of students' academic performance in biology in senior secondary school. *International Journal of Research and Analytical Reviews*, *3*(3), 1–8. http://www.ijrar.com/upload_issue /ijrar_issue_300.pdf.

Saka, A. O., & Onanuga, P. A. (2022). Achievement motivation and students' achievement in secondary biology: is the relationship mediated by cognitive style? Sakarya. *University Journal of Education*, *12*(1), 58–76. https://doi.org/10.19126/suje.980052.

Sanchez-Acevedo, M., & Kao, R. M. (2022). From development to function: hands-on & inexpensive clay modelling of mammalian kidney development. *The American Biology Teacher*, *84*(3), 172–175. https://doi.org/10.1525/abt.2022.84.3.172.

Setiwan, A., Koderi, W., & Pratiwi, W. (2020). Game based learning in mathematics: future teachers' viewpoint. *Journal for the Mathematics Education and Teaching Practices*, *1*(2), 87–93. https://dergipark.org.tr/en/download/article-file/1433554 .

Shemy, N. S. (2021). The effectiveness of interactive e-books in the development of scientific concepts during "science course" and its relation to the difference of cognitive style (verbal/visual) in students. *European Journal of Open Education and E-Learning Studies*, *6*(1), 60–78. https://doi.org/10.46827/ejoe.v5i2.3570.

Singh, S., & Dutt, S. (2022). Effecting the change: problem based learning as a pedagogy to improve achievement in physics in relation to cognitive. *ECS Transactions*, *107*(1). https://doi.org/10.1149/10701.8361ecst/meta.

Sulaiman, M. M., & Bello, G. (2022). Effects of metaphor instructional strategy on senior school students achievement in genetics in Ilorin, Nigeria. *International Journal of Educational Research Review*, *7*(3), 165–175. https://dergipark.org.tr/en/download/article -file/2352485.

Taştan, S. B., Mehdi, S., Davoudi, M., Masalimova, A. R., Bersanov, A. S., Kurbanov, R. A., Boiarchuk, A. V, & Pavlushin, A. A. (2018). The Impacts of Teacher's Efficacy and Motivation on Student's Academic Achievement in Science Education among Secondary and High School Students. *EURASIA Journal of Mathematics Science and Technology Education*, *14*(6), 2353–2366. https://doi.org/10.29333/ejmste/89579.

Witkin, H. A. (1973). The role of cognitive style in academic performance and in teacher-student relations. *Educational Testing Service Research Bulletin Series*, *1*, 2333–8504. https://doi.org/10.1002/j.2333-8504.1973.tb00450.x.

Witkin, H. A., Oltman, P. K., Raskin, E., & Karp, S. A. (1971). *A manual for the embedded figures tests.* ,. Consulting Psychologists Press.