Learning Analytics Indicators and The Development of Problem-Solving Skills in Chemistry: A Historical Cohort Study of Secondary School Students in Bayelsa State, Nigeria

Amangele Iyenemi Crystal (PhD)
Science Education Department
Faculty of Education, Niger Delta University,
Wilberforce Island, Bayelsa State
crystalgele@gmail.com
Phone number: 08037501822
https://doi.org/10.56201/ijccp.vol.12.no2.2026.pg122.131

Abstract
This study examined learning analytics indicators and the development of problem-solving skills in Chemistry among secondary school students in Federal Unity Colleges in Bayelsa State, Nigeria, between 2020 and 2025. Specifically, the study assessed trends in learning analytics indicators and determined changes in students' Chemistry problem-solving skills over the observation periods. A quantitative historical cohort research design was adopted, involving 250 students with 750 student-period records across three observation waves. Data were obtained from existing academic records using two structured instruments: the Learning Analytics Data Extraction Checklist (LADEC) and the Chemistry Problem-Solving Skills Assessment Record (CPSSAR). Descriptive statistics, including means and standard deviations, were employed to answer the research questions, while Gaussian generalised estimating equation models were used to test the null hypotheses at the 0.05 level of significance. The findings revealed that attendance, classroom participation, and assignment completion remained relatively stable across the observation periods, with no statistically significant changes ($p > .05$). However, formative assessment performance increased significantly from 53.30% to 58.32% ($p < .001$). Similarly, students' Chemistry problem-solving scores increased from 47.92% in the first observation wave to 56.73% in the third, representing a statistically significant improvement, $\chi^2(2) = 98.60$, $p < .001$. The study concluded that learning analytics indicators exhibited different longitudinal patterns, while Chemistry problem-solving performance improved significantly over time. It was recommended that Chemistry teachers and school administrators adopt multidimensional learning analytics practices and strengthen structured problem-solving activities and competency-based assessments to support students' cognitive development.

Keywords: *Learning analytics indicators, problem-solving skills, Chemistry education, historical cohort study, secondary school students, Bayelsa State.*

Introduction

The development of problem-solving skills remains a fundamental objective of Chemistry education, particularly as contemporary educational systems increasingly emphasise critical thinking, scientific reasoning, and knowledge application. Beyond memorising chemical

concepts, students are expected to interpret scientific information, analyse unfamiliar situations, and formulate appropriate solutions. The Organisation for Economic Co-operation and Development (OECD, 2024) emphasised the importance of developing higher-order cognitive competencies that enable students to address complex problems. In Chemistry, these competencies are essential for understanding abstract concepts, interpreting chemical reactions, and solving quantitative problems. Raman et al. (2024) demonstrated the potential of problem-based learning to enhance students' problem-solving skills, while Vo et al. (2025) highlighted the importance of instructional scaffolding in developing scientific reasoning. Nevertheless, conventional assessments frequently prioritise academic achievement without adequately capturing the progressive development of problem-solving competence.

The emergence of learning analytics has introduced opportunities for examining students' learning experiences through systematically collected educational data. Learning analytics indicators, including attendance, classroom participation, assignment completion, assessment performance, and learning engagement, provide measurable information about students' educational activities. Alhazbi et al. (2024) demonstrated the relevance of learning analytics in understanding self-regulated learning behaviours. However, measurable participation does not necessarily indicate meaningful cognitive engagement or improved problem-solving proficiency. Bergdahl et al. (2024) observed that learning analytics research predominantly emphasises behavioural indicators, often neglecting cognitive and other dimensions of engagement. Similarly, Bond et al. (2023) identified conceptual inconsistencies and limited evidence concerning the contribution of learning analytics to improved learning outcomes in primary and secondary education. These limitations highlight the need for more rigorous investigations of learning analytics indicators within specific educational contexts.

Furthermore, understanding students' learning characteristics requires attention to their development over time. Cross-sectional assessments provide limited evidence of changes in learning behaviours and cognitive competencies, particularly in Chemistry, where problem-solving skills develop progressively through conceptual understanding and repeated application. A prospective cohort design offers opportunities to observe students across successive instructional periods, thereby documenting changes in learning analytics indicators and problem-solving competence without manipulating their learning conditions.

In Nigeria, improving Chemistry learning outcomes remains an important educational priority. Faith et al. (2023) examined instructional strategies and Chemistry achievement among students in Delta and Bayelsa States; however, academic achievement does not necessarily reflect independent problem-solving competence. Moreover, UNESCO (2023) emphasised the importance of contextual appropriateness when applying educational technologies and data-informed practices. Despite growing research interest, the reviewed literature provides limited longitudinal evidence concerning learning analytics indicators and Chemistry problem-solving development among secondary school students in Bayelsa State.

Consequently, this study adopts a prospective cohort design to assess learning analytics indicators and determine the development of problem-solving skills in Chemistry among secondary school students in Bayelsa State, Nigeria, over successive observation periods. The findings are expected to inform contextually appropriate educational assessment practices and contribute to understanding students' learning trajectories.

Aim and Objectives of the Study

The aim of this study is to investigate the extent to which learning analytics indicators predict the development of problem-solving skills in Chemistry among secondary school students in Bayelsa State, Nigeria, using a historical cohort research design. Specifically, the study achieved the following:

1. Assess the learning analytics indicators of Chemistry students in secondary schools in Bayelsa State, Nigeria, over the study period.
2. Determine the level of development of problem-solving skills in Chemistry among secondary school students in Bayelsa State, Nigeria, over the study period.

Research Questions

The following research questions guided the study:

1. What are the trends in learning analytics indicators among secondary school Chemistry students in Bayelsa State, Nigeria, from 2020 to 2025?
2. What are the trends in the development of problem-solving skills in Chemistry among secondary school students in Bayelsa State, Nigeria, from 2020 to 2025?

Research Hypotheses

The following null hypotheses were tested at the 0.05 level of significance:

H_{01}: There is no statistically significant change in the learning analytics indicators of secondary school Chemistry students in Bayelsa State, Nigeria, from 2020 to 2025.

H_{02}: There is no statistically significant change in the problem-solving skills of secondary school Chemistry students in Bayelsa State, Nigeria, from 2020 to 2025.

Research Methods

The study adopted a quantitative historical cohort research design to examine learning analytics indicators and the development of problem-solving skills in Chemistry among secondary school students in Federal Unity Colleges in Bayelsa State, Nigeria, between 2020 and 2025. The design involved the retrospective examination of students' academic records to establish longitudinal patterns in learning activities and Chemistry problem-solving performance. The study covered three Federal Unity Colleges: Federal Government College, Odi; Federal Government Girls' College, Imiringi; and Federal Science and Technical College, Tungbo. The target population comprised senior secondary school students who studied Chemistry in these institutions during the period under investigation. A census approach was adopted at the institutional level, while criterion-based sampling was employed to select eligible student records. Records were considered eligible when they contained identifiable student information, documented learning activities, and comparable Chemistry assessments across at least two observation periods. The final sample comprised 270 students whose records satisfied the inclusion criteria.

Data were extracted using two structured instruments: the Learning Analytics Data Extraction Checklist (LADEC) and the Chemistry Problem-Solving Skills Assessment Record (CPSSAR). The LADEC captured attendance patterns, classroom participation, assignment completion rates, and formative assessment performance, while the CPSSAR documented students' demonstrated abilities to interpret Chemistry problems, apply relevant chemical principles, undertake quantitative reasoning, and evaluate solutions. The instruments were subjected to content validation by specialists in Chemistry education, educational measurement, and learning analytics to establish their relevance and adequacy. The consistency of extracted data was

examined through preliminary record assessment, while the comparability of historical assessment scores was evaluated across academic sessions. Where archived assessment responses required independent scoring, inter-rater agreement was assessed to establish scoring consistency.

Relevant data were retrieved from attendance registers, assignment records, continuous assessment registers, and archived Chemistry assessment materials maintained by the participating institutions. Student records were assigned unique identification codes to facilitate longitudinal tracking while preserving confidentiality. The extracted data were organised according to academic sessions and student cohorts, allowing changes in learning analytics indicators and problem-solving skills to be examined across successive observation periods. Records containing substantial missing information or insufficient evidence of problem-solving competence were excluded from the corresponding analyses.

Data were analysed using descriptive and inferential statistical procedures. Frequencies, percentages, means, and standard deviations were employed to describe learning analytics indicators and Chemistry problem-solving performance across the study period. Linear mixed-effects models were used to examine longitudinal changes in each study variable while accounting for repeated observations within students and differences in available follow-up measurements. Separate models were fitted for learning analytics indicators and Chemistry problem-solving scores to maintain the independence of the study objectives. Statistical hypotheses were tested at the 0.05 significance level, and effect estimates with 95% confidence intervals were reported. Ethical principles relating to educational research were observed through institutional authorisation, anonymisation of student records, restricted access to identifiable information, and confidential handling of extracted data.

Results

The dataset comprised 250 students with three annual observation waves per student, yielding 750 student-period records. The observations covered the 2020/2021 to 2024/2025 academic sessions and represented three entry cohorts. Results were organised according to the two research questions and corresponding null hypotheses.

Answers to Research Questions

Research Question One: What are the trends in learning analytics indicators among secondary school Chemistry students in Bayelsa State, Nigeria, from 2020 to 2025?

Table 1: Descriptive statistics of learning analytics indicators across three observation waves

Learning analytics indicator	Wave 1 Mean ± SD	Wave 2 Mean ± SD	Wave 3 Mean ± SD
Attendance (%)	75.29 ± 14.91	75.42 ± 15.09	75.93 ± 14.77
Classroom participation (%)	58.64 ± 15.52	58.80 ± 16.42	57.59 ± 15.81
Assignment completion (%)	68.29 ± 16.68	68.25 ± 17.73	67.88 ± 16.56
Formative assessment (%)	53.30 ± 18.75	54.80 ± 19.10	58.32 ± 18.96

Source: Field Survey (2026)

The results in Table 1 reveal variations in learning analytics indicators across the three observation waves. Students' mean attendance rates remained relatively stable, increasing marginally from 75.29% in Wave 1 to 75.93% in Wave 3. Classroom participation showed a

slight decline from 58.64% to 57.59%, while assignment completion decreased marginally from 68.29% to 67.88%. In contrast, formative assessment performance increased consistently from 53.30% in Wave 1 to 58.32% in Wave 3. These findings suggest that while the behavioural indicators of learning remained relatively stable, formative assessment performance demonstrated a more pronounced upward trend.

Research Question Two: What are the trends in the development of problem-solving skills in Chemistry among secondary school students in Bayelsa State, Nigeria, from 2020 to 2025?

Table 2: Descriptive statistics of Chemistry problem-solving skills across three observation waves

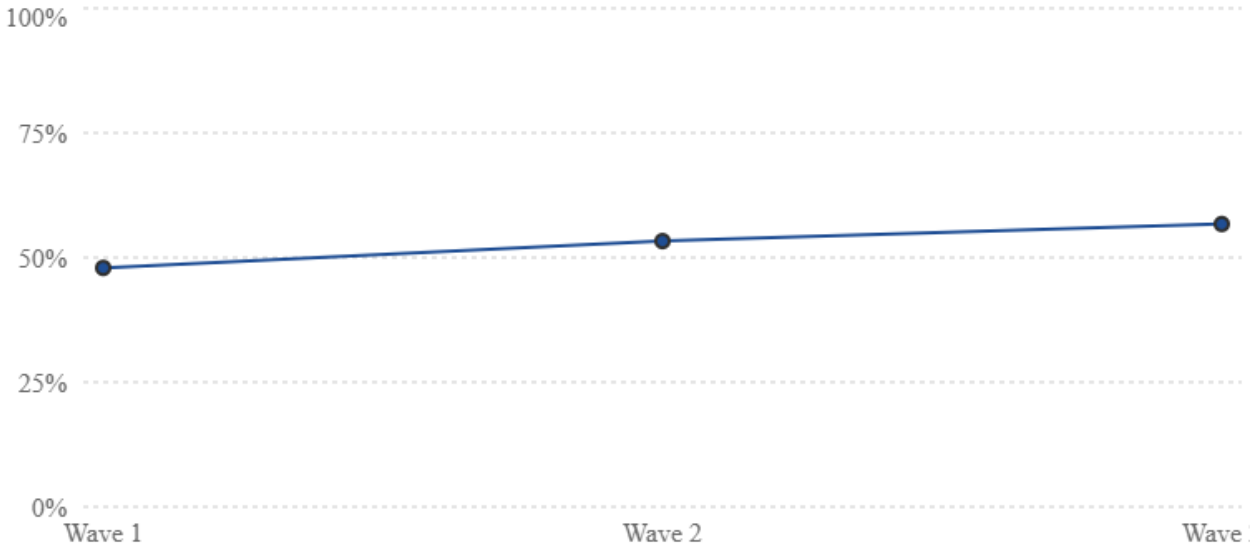
Observation wave	N	Mean score (%)	SD
Wave 1	223	47.92	22.96
Wave 2	227	53.30	21.88
Wave 3	226	56.73	20.58

Source: Field Survey (2026)

Table 2 indicates a progressive increase in students' mean Chemistry problem-solving scores across the observation waves. The mean score increased from 47.92% in Wave 1 to 53.30% in Wave 2 and subsequently to 56.73% in Wave 3, representing an overall descriptive increase of 8.81 percentage points. Furthermore, the standard deviation decreased from 22.96 to 20.58, indicating a modest reduction in score dispersion. These findings suggest an upward trajectory in students' demonstrated Chemistry problem-solving performance across the observation periods.

Chemistry problem-solving scores across observation waves

Mean percentage scores from the illustrative dataset



Testing of Hypotheses

The two null hypotheses were tested at the 0.05 level of significance using Gaussian GEE models with an exchangeable within-student correlation structure. Observation wave was treated as a categorical variable for omnibus tests of change. Additional linear-trend estimates were calculated to describe the direction and magnitude of change per successive wave.

Hypothesis One (H_{01}): There is no statistically significant change in the learning analytics indicators of secondary school Chemistry students in Bayelsa State, Nigeria, from 2020 to 2025.

Table 3: GEE analysis of changes in learning analytics indicators across observation waves

Indicator	Wald χ^2 (df = 2)	p-value	Decision
Attendance	0.69	.710	Not significant
Classroom participation	1.71	.425	Not significant
Assignment completion	0.05	.973	Not significant

Source: Field Survey (2026)

The results in Table 3 indicate that changes in attendance, classroom participation, and assignment completion were not statistically significant ($p > .05$). However, formative assessment performance demonstrated a statistically significant difference across the observation waves, $\chi^2(2) = 22.10$, $p < .001$. The corresponding linear-trend model estimated an average increase of 2.55 percentage points per wave (95% CI [1.47, 3.63], $p < .001$). Consequently, the first null hypothesis was rejected for formative assessment performance but not rejected for the other three learning analytics indicators. This indicates that the results provide evidence of changes in formative assessment performance, whereas the behavioural indicators remained statistically stable.

Hypothesis Two (H_{02}): There is no statistically significant change in the problem-solving skills of secondary school Chemistry students in Bayelsa State, Nigeria, from 2020 to 2025.

Table 4: GEE analysis of changes in Chemistry problem-solving skills across observation waves

Statistical parameter	Result
Valid student-period observations	676
Wald χ^2	98.60
Degrees of freedom	2

Source: Field Survey (2026)

Table 4 reveals a statistically significant change in students' Chemistry problem-solving skills across the observation waves, $\chi^2(2) = 98.60$, $p < .001$. The linear-trend analysis indicated an estimated increase of 4.73 percentage points per successive wave (95% CI [3.80, 5.67], $p < .001$). Therefore, the second null hypothesis was rejected. The results indicate that students' Chemistry problem-solving scores increased significantly across the three observation periods. However, this finding does not establish that changes in learning analytics indicators caused the improvement in problem-solving skills.

Discussion of Findings

The first objective examined the trends in learning analytics indicators among Chemistry students in Federal Unity Colleges in Bayelsa State, Nigeria, between 2020 and 2025. The findings revealed variations in the four indicators, with attendance increasing marginally from 75.29% to 75.93%, classroom participation declining from 58.64% to 57.59%, and assignment completion decreasing slightly from 68.29% to 67.88%. These changes were not statistically significant ($p > .05$), suggesting relative stability in students' observable learning behaviours across the observation periods. However, formative assessment performance increased significantly from 53.30% to 58.32% ($p < .001$), indicating measurable improvement in this dimension of academic performance. The divergence between relatively stable behavioural

indicators and improving assessment scores suggests that increased academic performance does not necessarily require corresponding increases in observable learning activities. This finding is consistent with Bergdahl et al. (2024), who established that learning analytics research predominantly emphasises behavioural engagement, despite its limited capacity to capture deeper cognitive processes. Similarly, Bond et al. (2023) identified conceptual inconsistencies in measuring student engagement and cautioned against assuming that observable learning activities necessarily translate into improved educational outcomes. Consequently, the findings underscore the importance of evaluating learning analytics indicators independently rather than interpreting them as interchangeable measures of students' educational development.

The significant improvement in formative assessment performance, despite the absence of statistically significant changes in attendance, classroom participation, and assignment completion, raises important questions regarding the interpretation of learning analytics indicators within secondary school Chemistry education. One plausible explanation is that students became more proficient in applying previously acquired knowledge or responding to assessment demands without substantially altering their recorded participation patterns. Nevertheless, the historical cohort design did not directly establish the learning mechanisms responsible for these changes. Alhazbi et al. (2024), in their systematic review of learning analytics and self-regulated learning, demonstrated that commonly employed indicators frequently emphasise observable activities and time-management behaviours without adequately validating their correspondence with underlying learning processes. The present findings reinforce this methodological concern by showing that individual learning analytics indicators exhibited different longitudinal patterns. Furthermore, the absence of significant changes in behavioural indicators should not be interpreted as evidence of ineffective learning, since attendance and task completion provide limited information about the quality of students' cognitive engagement. The findings therefore highlight the need for multidimensional approaches to educational monitoring that distinguish behavioural participation from demonstrated academic performance, particularly in contexts where learning analytics relies predominantly on conventional school records.

The second objective investigated the development of problem-solving skills in Chemistry among secondary school students in Federal Unity Colleges in Bayelsa State between 2020 and 2025. The findings revealed a progressive increase in mean problem-solving scores from 47.92% in the first observation wave to 53.30% in the second and 56.73% in the third. The observed improvement was statistically significant, $\chi^2(2) = 98.60$, $p < .001$, with an estimated increase of 4.73 percentage points per successive wave. These results indicate a positive trajectory in students' demonstrated Chemistry problem-solving competence across the observation periods. The findings are consistent with Raman et al. (2024), whose systematic review established that problem-based learning approaches can enhance students' problem-solving abilities in Chemistry. Similarly, Vo et al. (2025) emphasised the importance of conceptual understanding, metacognitive processes, and appropriate instructional scaffolding in supporting Chemistry problem-solving. Although the present study did not directly examine the instructional strategies responsible for the observed improvement, the findings suggest that students' problem-solving performance can develop progressively across successive periods of Chemistry instruction. The reduction in score dispersion from 22.96 to 20.58 further indicates a modest narrowing of performance differences among the observed students, although this descriptive pattern does not establish uniform improvement across individuals.

The observed improvement in Chemistry problem-solving skills has important implications for understanding students' cognitive development within the secondary school curriculum. Chemistry problem-solving involves more than recalling scientific facts; it requires identifying relevant information, selecting appropriate chemical principles, organising logical procedures, performing calculations, and evaluating the accuracy of solutions. The significant upward trend observed in this study may reflect cumulative learning experiences and increasing familiarity with Chemistry concepts and problem-solving procedures. This interpretation is supported by Vo et al. (2025), who identified the importance of scaffolding both content-specific knowledge and metacognitive processes, while highlighting unresolved questions concerning how instructional support should be progressively withdrawn as students develop greater independence. However, differences in assessment difficulty, curricular content, and students' prior knowledge may also have contributed to the observed score changes. Consequently, the findings should be interpreted as evidence of improved recorded problem-solving performance rather than definitive proof of equivalent growth in all underlying cognitive competencies. The study contributes longitudinal evidence on Chemistry problem-solving trajectories within the selected Federal Unity Colleges and underscores the importance of incorporating explicit problem-solving assessments into routine educational evaluation. Such assessments may provide more meaningful information about students' cognitive development than reliance on overall Chemistry achievement scores alone.

Conclusion

The study concluded that learning analytics indicators and Chemistry problem-solving skills exhibited distinct developmental patterns among secondary school students in Federal Unity Colleges in Bayelsa State, Nigeria, between 2020 and 2025. While attendance, classroom participation, and assignment completion remained relatively stable without statistically significant changes, formative assessment performance demonstrated significant improvement across the observation periods. Similarly, students' Chemistry problem-solving skills improved significantly, indicating a positive trajectory in their demonstrated ability to address Chemistry-related problems. These findings suggest that improvements in academic performance and problem-solving competence may occur without corresponding increases in observable behavioural engagement, highlighting the limitations of relying exclusively on attendance, participation, and assignment completion as indicators of meaningful learning. The study therefore underscores the importance of adopting multidimensional learning analytics frameworks that distinguish behavioural engagement from cognitive performance and incorporate explicit assessments of problem-solving skills. Nevertheless, the observed improvements should not be interpreted as causal effects of learning analytics indicators, given the observational nature of the study. The findings provide a basis for strengthening data-informed assessment practices, monitoring students' cognitive development, and informing future longitudinal research on Chemistry education in Nigerian secondary schools.

Recommendations

1. School administrators and Chemistry teachers should adopt multidimensional learning analytics practices that integrate behavioural engagement indicators with formative assessment performance to ensure comprehensive monitoring of students' learning progress.

2. Chemistry teachers should strengthen the use of structured problem-solving activities, instructional scaffolding, and regular competency-based assessments to sustain and enhance students' problem-solving skills across successive academic sessions.

IJCCP

References

Alhazbi, S., Al-ali, A., Tabassum, A., Al-Ali, A., Al-Emadi, A., Khattab, T., & Hasan, M. A. (2024). Using learning analytics to measure self-regulated learning: A systematic review of empirical studies in higher education. Journal of Computer Assisted Learning, 40(4), 1658–1674. https://doi.org/10.1111/jcal.12982

Bergdahl, N., Bond, M., Sjöberg, J., Dougherty, M., & Oxley, E. (2024). Unpacking student engagement in higher education learning analytics: A systematic review. International Journal of Educational Technology in Higher Education, 21, Article 63. https://doi.org/10.1186/s41239-024-00493-y

Bond, M., Viberg, O., & Bergdahl, N. (2023). The current state of using learning analytics to measure and support K–12 student engagement: A scoping review. In Proceedings of the 13th International Learning Analytics and Knowledge Conference (pp. 240–249). Association for Computing Machinery. https://doi.org/10.1145/3576050.3576085

Faith, O. A., Kachikwu, E. S. J., & Amakeke, I. J. (2023). Effects peer tutoring, study question-based instructional strategies and lecture method on students' academic achievement and attitude towards chemistry in Delta and Bayelsa States. Journal of Education and Practice, 14(33). https://doi.org/10.7176/JEP/14-33-03

Organisation for Economic Co-operation and Development. (2024). PISA 2022 results (Volume III): Creative minds, creative schools. OECD Publishing. https://doi.org/10.1787/765ee8c2-en

Raman, Y., Surif, J., & Ibrahim, N. H. (2024). The effect of problem based learning approach in enhancing problem solving skills in chemistry education: A systematic review. International Journal of Interactive Mobile Technologies, 18(5), 91–111. https://doi.org/10.3991/ijim.v18i05.47929

United Nations Educational, Scientific and Cultural Organization. (2023). Global education monitoring report 2023: Technology in education—A tool on whose terms? https://www.unesco.org/gem-report/en/publication/technology

Vo, K., Sarkar, M., White, P. J., & Yuriev, E. (2025). Exploring problem-solving scaffolds in general chemistry: A systematic review of scaffolding goals and instructional approaches. Journal of Chemical Education, 102(3), 1004–1018. https://doi.org/10.1021/acs.jchemed.4c01327