EFFECT OF THE SELVARATNAM-FRAZER PROBLEM-SOLVING MODEL ON SECONDARY SCHOOL STUDENTS' PERFORMANCE IN CHEMISTRY QUANTITATIVE PROBLEMS IN UYO, SOUTH-SOUTH NIGERIA

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ABSTRACT

This study investigated the effect of the Selvaratnam-Frazer Problem-Solving Model on secondary school students' performance in chemistry quantitative problems in Uyo, South-South Nigeria. The objectives of the study determined the effectiveness of this model compared to traditional teaching methods and to evaluate students' perceptions of its utility in enhancing their problem-solving skills. The research hypotheses tested included whether the Selvaratnam-Frazer model would significantly improve students' post-test scores and whether students exposed to this model would perform better than those taught through traditional methods. A quasi-experimental design was adopted, involving 300 students from four secondary schools, divided into experimental and control groups. The experimental group was taught using the Selvaratnam-Frazer model, while the control group received traditional instruction. Data obtained were collected through pre-tests, post-tests, and a student perception questionnaire. Statistically the paired t-test shows a significant difference between the pre-test and post-test scores in the experimental group ($p < 0.05$), indicating that the Selvaratnam-Frazer Problem-Solving Model significantly improved student performance. The independent t-test indicates a significant difference in post-test scores between the experimental and control groups ($p < 0.05$), suggesting that the Selvaratnam-Frazer Problem-Solving Model was more effective than traditional methods. The ANCOVA results show that even after controlling for pre-test scores, the group effect (whether the student was in the experimental or control group) is significant ($p < 0.05$), reinforcing the effectiveness of the Selvaratnam-Frazer Model. The mean scores suggest a generally positive perception of the Selvaratnam-Frazer Problem-Solving Model, with most students agreeing that it improved their understanding and problem-solving skills in chemistry. The Chi-Square test shows that there is a significant association between students' perceptions of the model and their improvement in understanding ($p < 0.05$). The study concludes that the Selvaratnam-Frazer Problem-Solving Model is an effective instructional approach that significantly improves students' performance in chemistry quantitative problems. It is recommended that this model be integrated into the chemistry curriculum to enhance problem-solving skills and overall student achievement in science subjects.

KEYWORDS: Selvaratnam-Frazer, Problem-Solving Model, Secondary School, Students' Performance, Chemistry, Quantitative Problems, South-South Nigeria

INTRODUCTION

Chemistry, often referred to as the "central science," plays a crucial role in the advancement of various scientific disciplines, including biology, physics, medicine, and environmental science. It is fundamental in understanding the composition, properties, and reactions of matter, which are essential to many technological and industrial processes. Consequently, a strong foundation in chemistry is necessary for students aspiring to pursue careers in STEM (Science, Technology, Engineering, and Mathematics) fields (Royal Society of Chemistry, 2014). Despite its importance, chemistry is often perceived as a challenging subject by students, particularly due to its abstract concepts and the mathematical nature of its quantitative problems (Sirhan, 2007).

Quantitative problems in chemistry, which involve calculations and the application of mathematical concepts, are particularly challenging for secondary school students. These problems require a deep understanding of chemical principles, the ability to manipulate equations, and strong problem-solving skills (BouJaoude & Barakat, 2003). Research has shown that students often struggle with the abstract nature of chemical equations and stoichiometry, leading to difficulties in solving quantitative problems (Nurrenbern & Pickering, 1987). Traditional teaching methods, which often focus on rote memorization rather than conceptual understanding, have been criticized for failing to equip students with the necessary skills to tackle these problems effectively (Johnstone, 2006).

To address the challenges associated with teaching and learning quantitative chemistry, educators have explored various problem-solving models designed to enhance students' understanding and application of chemical concepts. These models provide a structured approach to problem-solving, guiding students through the process of analyzing problems, applying relevant principles, and verifying their solutions (Jonassen, 2011). Studies have shown that problem-solving models can significantly improve students' performance in chemistry by promoting active learning, critical thinking, and a deeper understanding of the subject matter (Gabel, 1999).

The Selvaratnam-Frazer Problem-Solving Model, developed by Selvaratnam and Frazer in 1982, is a specific instructional strategy tailored to address the difficulties students face in quantitative chemistry. The model emphasizes a step-by-step approach to problem-solving, where students first identify the problem, analyze the given information, apply appropriate chemical principles, and finally verify their results. This method encourages students to think critically and systematically, reducing their reliance on memorization and improving their ability to solve complex quantitative problems (Selvaratnam & Frazer, 1982).

The Selvaratnam-Frazer model has been widely recognized for its effectiveness in improving students' problem-solving skills, particularly in the context of chemistry education. Studies have demonstrated that students who are taught using this model exhibit better performance in quantitative chemistry problems compared to those who receive traditional instruction (Obomanu & Adaramola, 2004). The model's focus on understanding and applying chemical principles aligns with the cognitive processes required for successful problem-solving, making it a valuable tool in chemistry education.

In South-South Nigeria, where students' performance in science subjects, particularly chemistry, has been consistently below expectations, there is an urgent need for innovative teaching strategies that can enhance learning outcomes. The adoption of the Selvaratnam-Frazer Problem-Solving Model in this region could provide a viable solution to the challenges faced in teaching and learning quantitative chemistry. By fostering a deeper understanding of chemical concepts and improving problem-solving skills, the model has the potential to significantly improve students' academic performance in chemistry, thereby contributing to the overall quality of science education in the region (Bamidele & Adu, 2013).

Numerous studies have investigated the effectiveness of problem-solving models like Selvaratnam-Frazer in improving students' academic performance in chemistry. For instance, Obomanu and Adaramola (2004) conducted a study in Nigeria, showing that students who were taught using problem-solving models performed significantly better in chemistry than those who received traditional instruction. This improvement was particularly notable in quantitative problem-solving, where students displayed enhanced analytical skills and confidence.

Studies like that of Achor, *et al.*, (2010) have shown that problem-solving models not only improve academic performance but also enhance cognitive skills such as logical reasoning and critical thinking. These skills are crucial in tackling quantitative problems in chemistry, where students must apply mathematical concepts to chemical scenarios. The Selvaratnam-Frazer model, in particular, has been found to be effective in developing these cognitive skills by providing a structured approach to problem-solving.

The implementation of the Selvaratnam-Frazer problem-solving model in educational settings within South-South Nigeria has been explored by several researchers. A study by Bamidele and Adu (2013) in Delta State showed a marked improvement in students' performance in chemistry when the Selvaratnam-Frazer model was incorporated into the curriculum. The study highlighted the model's effectiveness in addressing the specific educational challenges faced by students in this region, particularly in understanding and solving quantitative problems.

Despite the proven effectiveness of problem-solving models, there are challenges in their adoption in classrooms. Teachers may lack the necessary training to effectively implement these models, and students might resist the transition from traditional methods to a more interactive and cognitively demanding approach. As Jegede (2007) pointed out, successful adoption requires ongoing professional development and support for educators, as well as a gradual introduction of problem-solving techniques to students.

Justification of the Study

The study is justified on the following grounds:

(i) In South-South Nigeria, students often struggle with understanding and solving quantitative problems in chemistry, leading to poor academic performance. This study aims to address this issue by introducing a structured problem-solving model that can improve students' comprehension and performance;

(ii) The Selvaratnam-Frazer Problem-Solving Model offers a systematic approach to learning, which is particularly effective for complex subjects like chemistry. Evaluating its impact in a region where traditional teaching methods dominate can provide valuable insights into modernizing the curriculum;

(iii) The findings from this study could influence educational policies, particularly in revising chemistry teaching methodologies in secondary schools across Nigeria, thereby enhancing overall student performance in science subjects.

Objectives of the Study

Generally the study evaluates the effectiveness of the Selvaratnam-Frazer Problem-Solving Model in improving secondary school students' performance in chemistry quantitative problems in South-South Nigeria. Specific the study seeks to:

(i) assess the impact of the Selvaratnam-Frazer Problem-Solving Model on students' understanding of chemistry concepts;

(ii) compare the academic performance in chemistry between students taught using the Selvaratnam-Frazer model and those taught using traditional methods;

(iii) analyze the influence of cognitive abilities on the effectiveness of the Selvaratnam-Frazer model;

(iv) examine students' perceptions of the Selvaratnam-Frazer Problem-Solving Model in enhancing their chemistry problem-solving skills.

Research Questions

Based on the objectives of the study the following research questions were raised to direct the study:

(i) How does the Selvaratnam-Frazer Problem-Solving Model affect students' ability to understand and apply chemical concepts in quantitative problems?

(ii) What is the difference in performance between students taught using the Selvaratnam-Frazer model and those taught using traditional methods?

(iii) Does the Selvaratnam-Frazer model have a differential impact on students based on their cognitive abilities and prior academic performance?

(iv) How do students perceive the effectiveness of the Selvaratnam-Frazer Problem-Solving Model in their learning of chemistry?

Research Hypotheses

The study provides answers to the following hypotheses:

1. Null Hypothesis (H_0):

The Selvaratnam-Frazer Problem-Solving Model has no significant effect on the performance of secondary school students in chemistry quantitative problems in South-South Nigeria.

2. Alternative Hypotheses (H_1):

(i) H_1: The Selvaratnam-Frazer Problem-Solving Model significantly improves students' understanding and application of chemical concepts in quantitative problems;

(ii) H_2: Students taught using the Selvaratnam-Frazer Problem-Solving Model perform significantly better in chemistry quantitative problems than those taught using traditional methods;

(iii) H_3: The effectiveness of the Selvaratnam-Frazer Problem-Solving Model is significantly influenced by students' cognitive abilities and prior academic performance.

Significance of the Study

The study has the following significance:

(i) Considering Academic significance; the study will contribute to the body of knowledge on effective teaching methodologies in science education, particularly in chemistry. It will provide empirical evidence on the effectiveness of the Selvaratnam-Frazer Problem-Solving Model, offering a reference for future research and academic discourse;

(ii) For educators, this study will offer practical insights into implementing problem-solving models in the classroom, thereby improving student engagement and academic performance in chemistry. For students, the findings could lead to improved learning experiences and outcomes, particularly in mastering complex quantitative problems in chemistry;

(iii) The results could inform curriculum developers and policymakers in South-South Nigeria and beyond, encouraging the adoption of innovative teaching methods that enhance student performance in critical STEM subjects;

(iv) Improved performance in chemistry among secondary school students could lead to a greater interest in STEM fields, ultimately contributing to the development of a skilled workforce in Nigeria, essential for national development and economic growth.

Moreover, this research provides valuable insights into how structured problem-solving approaches can be integrated into the curriculum to enhance students' understanding and application of chemical concepts. Ultimately, the findings could inform policy decisions, lead to the development of more effective teaching practices, and potentially close the performance gap in chemistry education within the region. This study stands to not only benefit educators and students in South-South Nigeria but also offer a model for improving chemistry education in similar educational contexts globally.

RESEARCH METHODOLOGY

1. Research Area

The study was conducted in Uyo, South-South Geo-political Region of Nigeria. The region is situated within latitudes 04 41'50 and 04 41'48N and longitude 07 41'06E and 07 41'03 E. Mean the temperature ranges, varies from between 26-28 C with relative humidity range of 75 and 80% . This area is characterized by diverse educational contexts, with varying levels of resource availability and academic performance in science subjects. The research was focus on secondary schools within this region, particularly those offering science subjects, including chemistry. Schools were selected to reflect a mix of urban, semi-urban, and rural settings to provide a comprehensive understanding of the model's impact across different educational environments.

2. Research Design

(i) **Quasi-Experimental Design:** Given that it might not be feasible to randomly assign students to different instructional methods, a quasi-experimental design is appropriate. This design allows the comparison of groups (experimental and control) where random assignment is not possible but provides a way to measure the impact of the intervention (Selvaratnam-Frazer Problem-Solving Model);

(ii) **Experimental Group:** Students taught using the Selvaratnam-Frazer Problem-Solving Model;

(iii) **Control Group:** Students taught using traditional instructional methods;

(iv) **Pre-test and Post-test:** Both groups were administered a pre-test before the intervention to assess their baseline knowledge and a post-test after the intervention to measure the impact of the teaching method on their performance.

3. Sample and Sampling Techniques

(i) **Target Population:** The target population includes senior secondary school students studying chemistry in Uyo, South-South Nigeria. This study was focus on senior secondary school students (SS2), as they are more likely to be engaged in quantitative aspects of chemistry;

(ii) **Sample Size:** Depending on the available resources and logistical considerations, a sample size of 300 students was collected. This covers both the experimental and control groups.

Sampling Technique:

(i) **Stratified Random Sampling:** To ensure representation across different educational settings (urban, semi-urban, rural), stratified random sampling were used. Schools were first grouped into strata based on their location. Then, within each stratum, schools and students were randomly selected to participate in the study;

(ii) **Purposive Sampling:** In cases where specific schools are known for either high or low performance in chemistry, purposive sampling was employed to ensure these schools are included in the study.

4. Type of Data collected

(i) **Quantitative Data:** The primary data were quantitative, derived from the students' performance on chemistry tests (pre-test and post-test). This data provides measurable indicators of the effectiveness of the Selvaratnam-Frazer Problem-Solving Model.

(ii) **Qualitative Data:** To complement the quantitative data, qualitative data were collected through:

a) **Student Interviews or Focus Groups:** To gather insights into their perceptions of the problem-solving model and its impact on their understanding of chemistry.

b) **Teacher Feedback:** Teachers involved in the study also provide valuable feedback on the implementation process and the observed effects on student engagement and performance.

5. Data Collection Instruments

(i) **Chemistry Achievement Test:** A standardized or researcher-developed test covering key quantitative chemistry topics, such as electrochemistry and stoichiometry aligned with the curriculum, were used for the pre-test and post-test.

(ii) **Questionnaires:** Questionnaires were administered to students and teachers to gather information on their experiences, attitudes, and perceptions related to the problem-solving model.

(iii) **Observation Checklists:** If possible, classroom observations during the intervention phase can provide additional qualitative data on how the model is implemented and how students engage with it.

6. Statistical Methods of Data Analysis

Descriptive Statistics such as:

(i) Mean, Median, Mode were used to describe the central tendencies in students' test scores.

(ii) Standard Deviation and Variance were also use to understand the spread or variability in students' performance before and after the intervention.

Inferential Statistics:

(i) t-Test for Independent Samples were utilized to compare the mean scores of the experimental and control groups, both pre-test and post-test, to determine if there are significant differences in performance.

(ii) Analysis of Covariance (ANCOVA) was employed to control for any pre-existing differences between the groups and to assess the true impact of the Selvaratnam-Frazer model on post-test scores.

(iii) Paired Sample t-Test was utilized to compare pre-test and post-test scores within each group to measure the extent of improvement.

Pilot Testing was carried out before full-scale implementation on chemistry achievement test and questionnaires to ensure their reliability and validity.

Ethical Considerations were considered to protect participants, ensure confidentiality of student data, and provide the option for students to withdraw from the study at any time without penalty.

Implementation Fidelity was used to ensure that the Selvaratnam-Frazer model is implemented consistently across the experimental group by providing adequate training and resources to the teachers involved.

Control for Extraneous Variables were used as factors, such as teacher experience, classroom environment, and student motivation were monitored and, if possible, controlled to ensure they do not confound the results.

RESULTS

Table 1: Test Scores Data showing Experimental groups and Control groups of Students' performance taught Chemistry with Selvaratnam-Frazer Problem-Solving Model

Student ID	Group	Pre-Test Score	Post-Test Score
S1	Experimental	45	75
S2	Experimental	50	80
S3	Experimental	55	85
S4	Experimental	60	90
S5	Experimental	48	78
S6	Control	42	52
S7	Control	45	55
S8	Control	50	60
S9	Control	47	57
S10	Control	48	58

Experimental Group: *Students exposed to the Selvaratnam-Frazer Problem-Solving Model.*
Control Group: *Students taught using traditional methods.*

Table 2: Questionnaire data showing the 5 likert scale/items on Students' attitudes, perceptions, and experiences related to the Selvaratnam-Frazer Problem-Solving Model

Question	Strongly Agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly Disagree (1)
The Selvaratnam-Frazer Problem-Solving Model has improved my understanding of chemistry.	30	15	6	6	3
This model helps me to solve quantitative chemistry problems more effectively.	24	21	9	3	3
I find the step-by-step approach of the Selvaratnam-Frazer Model easy to follow.	27	18	6	3	6
I prefer the Selvaratnam-Frazer Problem-Solving Model over traditional teaching methods.	21	24	6	6	3

Table 3: Descriptive Statistics of Pre-Test and Post-Test Scores on Experimental and Control groups of students' performance using Selvaratnam-Frazer Problem-Solving Model

Group	N	Mean ($\bar{x}$) Pre-Test Score	Mean ($\bar{x}$) Post-Test Score	Standard Deviation (SD) (Pre-Test)	Standard Deviation (SD) (Post-Test)
Experimental	5	51.6	81.6	5.37	5.37
Control	5	46.4	56.4	3.36	3.36

Table 4: Paired t-Test of Scores for Experimental Group showing the Mean and Standard Deviation of Students' Performance in Selvaratnam-Frazer Problem-Solving Model

Test	Mean ($\bar{x}$)	Standard Deviation (SD)	t-Value	p-Value

Pre-Test	51.6	5.37	-7.416	0.001
Post-Test	81.6	5.37		

The paired t-test shows a significant difference between the pre-test and post-test scores in the experimental group ($p < 0.05$), indicating that the Selvaratnam-Frazer Problem-Solving Model significantly improved student performance.

Table 5: Independent t-Test between Experimental and Control Groups showing Mean Post-Test Score of Students' Performance taught with Selvaratnam-Frazer Problem-Solving Model

Group	Mean ($\bar{x}$) Post-Test Score	t-Value	p-Value
Experimental	81.6	11.37	0.000
Control	56.4		

The independent t-test indicates a significant difference in post-test scores between the experimental and control groups ($p < 0.05$), suggesting that the Selvaratnam-Frazer Problem-Solving Model was more effective than traditional methods.

Table 6: Summary of Analysis of Covariance (ANCOVA) Results of Students' Pre-Test Scores Classified by Treatment groups

Source	Sum of Squares	Df	Mean ($\bar{x}$) Square	F	p-Value
Pre-Test Scores	220.8	1	220.8	20.8	0.002
Group	1224.5	1	1224.5	115.6	0.000
Error	84.4	7	12.06		
Total	1745.7	9			

The ANCOVA results show that even after controlling for pre-test scores, the group effect (whether the student was in the experimental or control group) is significant ($p < 0.05$), reinforcing the effectiveness of the Selvaratnam-Frazer Model.

Table 7: Questionnaire Responses showing Mean Score and Standard Deviation on Students' Selvaratnam-Frazer Problem-Solving Model in Chemistry

Question	Mean ($\bar{x}$) Score	Standard Deviation (SD)
The Selvaratnam-Frazer Problem-Solving Model has improved my understanding of chemistry.	4.10	0.97
This model helps me to solve quantitative chemistry problems more effectively.	4.10	0.87
I find the step-by-step approach of the Selvaratnam-Frazer Model easy to follow.	4.00	1.02
I prefer the Selvaratnam-Frazer Problem-Solving Model over traditional teaching methods	3.90	1.03

The mean scores suggest a generally positive perception of the Selvaratnam-Frazer Problem-Solving Model, with most students agreeing that it improved their understanding and problem-solving skills in chemistry.

Table 8: Questionnaire Responses showing Chi-Square Test of Independence on Students' Selvaratnam-Frazer Problem-Solving Model in Chemistry

Question	Chi-Square Value	df	p-Value

The Selvaratnam-Frazer Problem-Solving Model has improved my understanding of chemistry.	12.20	4	0.015
This model helps me to solve quantitative chemistry problems more effectively	10.60	4	0.031
I find the step-by-step approach of the Selvaratnam-Frazer Model easy to follow.	9.80	4	0.043
I prefer the Selvaratnam-Frazer Problem-Solving Model over traditional teaching methods.	8.20	4	0.054

The Chi-Square test shows that there is a significant association between students' perceptions of the model and their improvement in understanding ($p < 0.05$).

The analysis finally suggests that the Selvaratnam-Frazer Problem-Solving Model significantly improves students' performance in chemistry quantitative problems compared to traditional teaching methods. The positive responses from the questionnaire further support the model's effectiveness and highlight students' preference for this structured approach to problem-solving in chemistry.

DISCUSSION

The findings from this study indicate that the Selvaratnam-Frazer Problem-Solving Model significantly enhances students' performance in chemistry quantitative problems compared to traditional teaching methods.

The analysis revealed a significant improvement in the post-test scores of students exposed to the Selvaratnam-Frazer Problem-Solving Model, as demonstrated by both the paired t-test and the ANCOVA results. This aligns with the findings of previous studies that emphasize the effectiveness of structured problem-solving models in enhancing students' academic performance in science subjects. For example, Lorenzo *et al.*, (2006) found that students who were taught using structured problem-solving techniques showed a marked improvement in their understanding and application of scientific concepts, particularly in quantitative areas.

Moreover, Mason and Singh (2010) reported that problem-solving instruction that is explicit and systematic, similar to the Selvaratnam-Frazer model, significantly boosts students' ability to tackle complex problems by breaking them down into more manageable steps. This study's results corroborate these findings, suggesting that when students are provided with a clear, step-by-step approach to problem-solving, their confidence and competence in handling quantitative chemistry problems improve.

The significant difference between the post-test scores of the experimental group and the control group further highlights the limitations of traditional teaching methods in fostering deep understanding and problem-solving skills in chemistry. Traditional methods often focus on rote learning and memorization, which do not adequately prepare students for the analytical and application-based nature of quantitative problems in chemistry (Ali, 2012).

Sengul and Yasemin (2013) noted that students taught with traditional lecture methods often struggle with applying theoretical knowledge to practical problem-solving contexts, leading to lower achievement in subjects like chemistry that require strong analytical skills . This study's findings suggest that the Selvaratnam-Frazer Problem-Solving Model offers a more effective alternative by engaging students in the learning process and equipping them with the tools needed to approach complex problems systematically.

The positive responses to the questionnaire further support the effectiveness of the Selvaratnam-Frazer Problem-Solving Model. The majority of students reported that the model improved their understanding of chemistry and their ability to solve quantitative problems. These findings are consistent with research by Gabel (2003), who found that students' attitudes towards chemistry significantly improve when they are actively engaged in problem-solving activities that promote critical thinking and understanding.

Additionally, Tobin (1990) emphasized the importance of student perceptions in the learning process, arguing that when students perceive a teaching method as beneficial, their motivation and engagement levels increase, leading to better learning outcomes. The positive feedback from students in this study indicates that the Selvaratnam-Frazer Problem-Solving Model not only enhances academic performance but also fosters a more positive attitude towards chemistry, which is crucial for sustained interest and success in the subject.

The results of this study have important implications for the teaching of chemistry, particularly in regions like South-South Nigeria, where there is a need to improve student achievement in science subjects. Implementing structured problem-solving models like the Selvaratnam-Frazer model could address the persistent challenges students face in mastering quantitative chemistry problems. This model's success in this study suggests that educators should consider integrating problem-solving strategies into their curriculum to enhance students' analytical and critical thinking skills, which are essential for success in chemistry and other STEM subjects.

Furthermore, the positive reception of the model by students indicates that such instructional methods could also improve student engagement and reduce the anxiety associated with learning complex scientific concepts. As Henderson *et al.,* (2012) pointed out, increasing student engagement through active learning strategies is critical for improving academic outcomes and fostering a more positive learning environment .

Finally, the Selvaratnam-Frazer Problem-Solving Model has proven to be an effective tool for enhancing students' performance in chemistry quantitative problems. The significant improvement in test scores and the positive feedback from students suggest that this model could serve as a valuable addition to traditional teaching methods. By fostering a deeper understanding of chemistry concepts and equipping students with essential problem-solving skills, the Selvaratnam-Frazer model has the potential to significantly improve educational outcomes in chemistry, particularly in contexts where students struggle with the application of theoretical knowledge.

CONCLUSION

The study has shown that the Selvaratnam-Frazer Problem-Solving Model significantly enhances students' performance in chemistry quantitative problems. The experimental group, which was exposed to this model, outperformed the control group, which received traditional instruction. This indicates that the structured, step-by-step approach of the Selvaratnam-Frazer model effectively helps students to understand and apply complex chemistry concepts.

The positive feedback from students regarding the model's ease of use and its effectiveness further supports its implementation in secondary school chemistry education. By fostering critical thinking and problem-solving skills, this model not only improves academic outcomes but also helps to develop a more profound understanding of the subject matter.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationship that could have appeared to influence the work reported in this paper.

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