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The Smartboard in Chemistry Classrooms: What is Its Effect on Chemistry Teaching and Learning in Selected Topics in Grade 11?

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Abstract. The study aimed to investigate the effect of using the smartboard on teaching and learning acid-base reactions by applying qualitative and quantitative calculations. The effect of the smartboard on knowledge retention of the concept application was examined and compared to traditional teaching methods. A quasi-experimental design with experimental and control groups using the pretest and posttest design was adapted for the study. A convenient sampling technique was used to select 284 Grade 11 students from an urban region of The Gambia. We prepared an achievement test with 15 questions to collect data. While the experimental group studied the topics using the smartboard, the control group studied using traditional teaching methods. The achievement test was prepared to measure the groups' differences in knowledge retention and application. The same test was applied to compare the pretest and posttest to measure group differences. The independent *t* test results showed a significant difference (p = .000) between the experimental group (M = 34.30, SD = 18.971) and the control group (M = 28.01, SD = 13.853). Furthermore, the results of the knowledge-retention rate were higher among the experimental group participants (M = 29.23, SD = 14.232) than in the control group (M = 26.72, SD = 12.673). This leads to the conclusion that using the smartboard provides an educative contribution to technology integration in the classroom, especially innovation in teaching and learning.

Keywords: academic achievement; chemistry teaching and learning; smartboard learning

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1. Introduction

The use of modern technology is fast growing in science teaching and learning, and most practitioners are looking to its use in classrooms to enhance learners' affective and cognitive domains. This domain has led to increased progress in science education in countries that have used technology and followed the technology rules. For example, nurturing creativity has promoted individuals to be productive due to the mastery of technology applications and expressing their potential in the scientific arena (Tall et al., 2021). On the other hand, countries that have not used technology and have not followed the technology rules have had setbacks in many aspects of development (Blonder & Mamlok-Naama, 2019). In particular, the quality of science education has affected students' ability to be qualified individuals even after completing school. Inadequate teaching and learning resources (Igharo et al., 2011), teacher quality (Ryoko & Tanya, n.d.), pedagogical approaches (Bayram-Jacobs et al., 2019), and inadequate content knowledge (Tall et al., 2021; Usak et al., 2011) are the current issues affecting quality science education. Kafyulilo et al. (2016) described instructional hours as inadequate, not permitting teachers to execute intensive, interactive engagement, including experimentation with chemical phenomena. Therefore, the common understanding is that new technology-based learning could alleviate the current status quo. Nonetheless, teachers may lose out on this opportunity if they do not apply technology knowledge and skills in a meaningful manner (Rosmansyah et al., 2022), as they are moving from traditional teaching to modern methods of teaching.

The smartboard is one of the current technology-based learning tools introduced in education systems. The United States of America, the United Kingdom, and Turkey are among the countries that have benefited from the outcomes of the smartboard in science education (Akar, 2020; Hanover Independent Research [HIR], 2016; Kirbas, 2018). Several studies have found that smartboards enhance learning environments, engage students, and facilitate effective lesson delivery. As a result of these conveniences, through the World Bank and New Jersey Centre for Teaching and Learning (NJCTL), the Ministry of Education, The Gambia, has invested extensively in providing smartboards to 12 selected secondary schools in the country. Technology-based learning is consistent with the policy goal (Ministries of BSE and HERST, 2016; Republic of The Gambia, 2004) to achieve changes in teaching dynamics, particularly in science and mathematics education. The Gambia has introduced smartboard instruction through the Progressive Science and Mathematics Initiative (PSMI). The social constructivism approach is the primary teaching strategy integrated with technology application instead of traditional teaching methods. This initiative has made teaching and learning apparent and interactive in the Gambian context (Hanover Research, 2014; Moussa et al., 2020; Ryoko & Tanya, n.d.).

Smartboard integration has been found to reduce the amount of physical equipment needed through multimedia learning objects (Phoong et al., 2019). Glassware and reagents for physical experimentation could be expensive for third-world countries, including The Gambia, but smartboard teaching and learning can be integrated with these as complement. Lesson courses, such as qualitative description and quantitative calculation or measurement of acid-base reactions, can be learned through virtual learning platforms (Aldosari et al., 2022) without physical interaction with the glassware or reagents. Davidovitch and Yavich (2017) further reiterated that by teaching with a smartboard, learning becomes flexible and interactive through different learning opportunities. Immediate feedback, for example, is one of the opportunities smartboards provide to promote learning, which might be challenging in a traditional classroom (Moore, 2021). Through interaction with the technology, teacher performance and student learning are improved (Tyagi et al., 2020).

Furthermore, a good number of studies have appreciated the promotion of conceptual understanding of concepts taught through smartboards (Aldalalah, 2021; Mihindo et al., 2017). For example, integrating the physics education technology (PhET) software into a smartboard demonstrates the mole ratio or concentration calculation. The variables can be adjusted by adding indicators or changing values or substance amounts. According to Aktas and Aydin (2016), such learning processes promote more permanent learning than learning through traditional methods. Therefore, to prepare students for a bright future, teachers must create an environment conducive to mastery and application rather than passive learning or memorization.

Besides, smartboards, as the current modern instructional tool, encourage application, student-centered learning, active participation, and student motivation (Kirbas, 2018). The use of automatic student response systems (clickers) in smartboards, for example, motivates students to participate and coordinates and monitors students' progress and learning challenges (Cutrim, 2008; Krajcik & Mun, 2014). During teaching, students can discuss in-class questions (formative questions) in groups before submitting their answers using the unique code assigned to each student in clickers. The percentages of their answers to A, B, C, or D are generated by the smartboard for everyone to see (Ryoko & Tanya, n.d.). In essence, if there are misconceptions or learning challenges, this will be reflected in the percentages of scores on the smartboard. Then, the task of the teacher is to restate the questions if there are divergent answers or continue to another question. In this approach, therefore, "waiting time" is encouraged in the class, which is another critical teaching and learning strategy (Bayram-Jacobs et al., 2019; Cutrim, 2008). Contrarily, in traditional classrooms, teachers may not encourage waiting time due to classrooms being overpopulated with students, inadequate instructional periods for a chemistry lesson (Kafyulilo et al., 2016), or their attitude towards chemistry teaching (Tabor, 2021).

In order to improve and promote waiting time, smartboard integration has replaced the classic or traditional application. While considering this modern technology, sample chemistry topics can be uploaded to investigate the learning difference by comparing them with the classic application. In this regard, this study intends to investigate if the smartboard could support the teaching and learning of topics that pose challenges for Gambian students, as enshrined in the Chief Examiners' Report (West African Examinations Council [WAEC], 2019).

These topics involve qualitative identification and interpretation of common substances into acidic or basic using pH scales and quantitative measurement and calculation of acid-base reactions. Students instructed through the smartboard are thus compared to those in traditional instruction.

Moreover, studies have shown significant differences in students' learning outcomes (Aktas & Aydin, 2016; Kirbas, 2018), but most of those studies concentrated on pre-service teachers or students and little on secondary school students. However, this study has taken a different approach by considering secondary school students' interaction with learning objects on the smartboard and learning the topics. In contrast, other students learn the same topics using textbook problem-solving and physical experimentation. A retention test is also conducted to determine their knowledge application and retention. Research has shown that the more students are exposed, the more permanent the learning event and the more they remember the concept (Aktas & Aydin, 2016; Aldosari et al., 2022).

Nevertheless, for students to remember what they have learned, paradigm-shifting is imperative and investigates how learning occurs. It can be determined which students have trouble grasping the topical learning of the material and which can perform better at learning the materials. This is because there is a common feeling that chemistry concepts are challenging to understand (Tekin & Kolomuc, 2011), especially with the traditional approach. There is thus a need for an alternative approach, such as smartboard integration, to engage students in active and permanent learning. Unfortunately, little is known about such an extensive technology investment in The Gambia. Researching the value of this investment to the nation and academia is just as crucial as making plans when deciding the planning procedure. In addition, The Gambia lacks data on learning retention and application in chemistry instruction supplemented by smartboards. Although there are a few evaluation studies on national examination results (Hanover Research, 2014; Moussa et al., 2020; Ryoko & Tanya, n.d.), none focus on academic retention and application. Jammeh et al. (2022) highlighted some important information about Gambian teachers concerning technological pedagogical content knowledge in the smart classroom. On this premise, the following research questions guide the study:

1. What is the effect of the smartboard in chemistry teaching and learning among students in Grade 11?
2. What is the difference in terms of knowledge application between students taught using the smartboard or traditional teaching facilities?

2. Method and Materials

This section defines the data collection techniques employed, including the authorization granted to investigate the impact of using smartboards in chemistry teaching and learning. It also presents the participants, data sources, and variable measures.

2.1 Research Design

This study involved a quasi-experimental design with a control group. The complementing approach was pretest, posttest, and retention test design. This approach controls external variables by measuring the cause-and-effect relationships between variables (Dugard & Todman, 1995). In other words, smartboards were used by one group (experimental) and the other group (control group) used textbooks and chalkboard problem-solving. We used social constructivism learning as the integrated theory in the smartboard application and it guided the instructional interventions for about 24 days (see Akyol & Fer, 2010). For example, the experimental group learned the topic using learning concepts in smartboard. These processes included clarification, exploration, interaction, group discussion, sharing, and answering in-class questions using clickers. It also included physical experimentation. Conversely, the control group learned the topic using textbook problem-solving, note presentation on the blackboard, classwork, assignments, activity problem-solving, and answering in-class questions by raising hands. They, too, had to perform physical experimentation.

2.2 Participants

The study sample consisted of 284 students from secondary schools in the urban regions of The Gambia who were selected through a convenient sampling technique from 568 chemistry students. Regions 1 and 2 were selected due to the number of chemistry students and availability of smartboards in classrooms. Chemistry students in Grade 11 from both public and private schools were selected and divided equally into an experimental group (142 students) and a control group (142 students). Students from Grade 11 were chosen since this grade is the most important intermediate class in the education structure of The Gambia. In addition, as seen in the school records, the academic performance of the selected students concerning their work and academic records was similar.

2.3 Instrument

We developed 20 open-ended test items and categorized them under topics that pose challenges to students' learning at the final examination (WAEC, 2019). As highlighted in Table 1, these topics were used to ascertain participants' application and conceptual understanding instead of their behavior, as is the common practice in schools. Because there is no direct way to determine if students attain their educational goals, in this regard, three behavioral test items were derived directly from the previous items prepared by the WAEC. We prepared 17 items on conceptual understanding using the Aki-Ola core chemistry textbook for secondary schools and the Grade 11 chemistry curriculum. Item analysis was performed to identify defective items. This analysis identified the items' discriminant index, which separates participants' differences and to what degree. It also identified the items' difficulty index, which indicates the proportion of questions answered correctly and the number of students who did so. This process led us to determine the instrument's validity and reliability.

Table 1: Summary of instrument distribution

Sl.	Topic	Number of questions framed	
		In the draft tool	In the final tool
1.	Introductory concepts of acids, bases, and salts, which was an opportunity to test participants' prerequisite knowledge	2	2
2.	Substance identification or interpretation through pH scales and testing of common substances using indicators (red cabbage or red *camelina communis* flower, phenolphthalein, methyl orange, and bromothymol blue)	2	2
3.	Quantitative measurements of acids and bases	5	3
4.	Measurements and calculations of numerical values of the pH for each sample to determine color representation by comparing with values	5	4
5.	Titration of antiacids with distilled water, bromothymol blue indicator, and 1M HCl	3	2
6.	Weak acids-weak base titration and calculations	3	2
	Total	20	15

2.4 Validity and Reliability

For content validity purposes, 20 questions were prepared, reviewed, and validated using interrater reliability to ensure that the questions were factual, and the conceptual questions were applicable and critical. Questions that did not meet these criteria were revised by us and returned to the raters for re-scoring. Items that failed to meet the criteria after three rounds were excluded from the study, thus reducing the number to 18 items. Piloting took place using 40 Grade 11 students who had previously taken this course and were not part of the study sample to determine the test's reliability and discriminant level. Each response from students was graded for item analysis. The items with the highest scores were mentioned first. The highest group included 44% of the responses on the list. A sub-group was created using the exact number of the lowest scoring values through the difficulty index and the discriminant index concept on all items. In light of these findings, we chose to eliminate 3 questions, thus reducing the total number of test questions to 15. The reliability coefficient of the instrument was found to be 0.86 Cronbach alpha, which revealed to what extent the questions were measured according to the difference between the questions and the variance of these questions (Hinton et al., 2004).

2.5 Data Collection and Procedure

The data were collected after obtaining permission from the Ministry of Basic and Secondary Education, The Gambia. As for research assistance and support, national trainers in technology and pedagogy were used and guided. We organized weekly meetings to address any challenges that may have compromised the plans and implementation. Both groups were subjected to a pretest and a posttest after 24 days of teaching. An additional four weeks were provided for the two groups after the posttest without any activities to test for knowledge retention.

Participants in the experimental group were taught using learning objects in smartboard, including physical experimentation. Participants in groups explored, clarified, and discussed topics among themselves. As they were learning, challenges were encountered, and they used multimedia platforms (YouTube) or online search within the smartboard for alternative explanations. Within the lecture notes, participants attempted in-class questions through group discussions to convince one another before responding to the answers individually using their unique code in clickers. While in their groups, they explored and clarified by accessing functional tools (Activity-builder, image designer, etc.) in the smartboard, which promoted them to be knowledge creators and not consumers (Goodman et al., 2013).

In contrast, in the control group, participants were taught using textbook problem-solving and workbook exercises. The exercises were delivered utilizing traditional techniques or approaches, such as note-taking on the blackboard, presentation, explanation, direct questioning, hands-on activities, or physical experimentation to solve problems. They learned through lectures and physical experimental modes. Group discussion and interaction were encouraged as another important pedagogical approach in classrooms. However, participants responded to in-class questions during lectures by raising their hands.

Both groups were provided with constant electricity and internet connectivity to minimize interruption during the intervention. In addition, both groups were taught through the support of national trainers, which included one of the researchers of this study, using specific topics for about 24 days. These topics were: (i) introductory concepts of acids, bases, and salts to assess prior knowledge, (ii) substance identification or interpretation using pH scales and testing of common substances using indicators (red cabbage or red *camelina communis* flower, phenolphthalein, methyl orange, and bromothymol blue), (iii) quantitative measurements of acids and bases, and (iv) measurements and numerical pH values for each sample.

2.6 Data Analysis

The items in the achievement test were scored and recorded, which provided the resultant data. A point (1) was awarded for each correct answer on an item, while zero points (0) were awarded for incorrect or unanswered answers. The items were examined following the application of the two different statistical tests. Inferential statistics was used to determine the difference between the two independent groups before and after the intervention (that is, pretest & posttest). An independent sample *t* test was conducted comparing the two groups, while a dependent *t* test was conducted to compare the pretest and posttest scores of the groups at the .05 significance level. Statistical Package for Social Sciences (SPSS) 21 software was used for statistical data generation.

3. Results

Results obtained from the quantitative statistical analysis are discussed in Tables 2 to 6. The *t* test results of the pretest for the two independent groups are presented in Table 2, comparing means and standard deviations.

Table 2: Independent *t* test results of the pretest for both groups

Group	n	Mean	Standard deviation	*t*	df	Sig. (2-tailed)
Experimental	142	20.18	9.352	-5.516	282	0.003
Control	142	24.26	10.151			

The mean and standard deviation scores indicate that the two groups were significantly different (experimental = 20.18 & 9.352; control = 24.26 & 10.151), with $t = -5.516$, $p < .05$. This indicates that the groups differed, favoring the control group. However, their results from the first term academic year were not significantly different from their margin of difference in the pretest scores. The dependent *t* test results are presented in Table 3, comparing the means and standard deviations of the pretest and posttest of the experimental group.

Table 3: Dependent *t* test results of the pretest and posttest for the experimental group

Experimental group	n	Mean	Standard deviation	*t*	df	Sig. (2-tailed)
Pretest	142	20.18	9. 352	3.694	281	0.000
Posttest	141	35.30	18.971			

The results revealed that the pretest and posttest scores of the experimental group were significantly different ($t = 3.69$, $p < .05$). This indicates that after the application, there was a mean gain of 15.12 and a standard deviation of 9.619 (Table 3).

A similar analysis was conducted for the control group (Table 4), which also showed a significant difference in pretest and posttest scores ($t = 3.690$, $p < .05$). There were some improvements in the mean and standard deviation (M = 3. 75, SD = 3.702) with the use of the study approach on the control group compared with the smartboard for the experimental group.

Table 4: Dependent *t* test results of the pretest and posttest for the control group

Control group	n	Mean	Standard deviation	*t*	df	Sig. (2-tailed)
Pretest	142	24.26	10.151	3.690	282	0.000
Posttest	142	28.01	13.853			

We compared the posttest scores of the experimental and control groups (Table 5).

Table 5: Independent *t* test results of the posttest for both groups

Group	n	Mean	Standard deviation	*t*	df	Sig (2-tailed)
Experimental	141	35.30	18.971	3.694	281	0.000
Control	142	28.01	13.853			

The independent *t* test showed a positive improvement for both groups. For the posttest, the experimental group's mean was 35.30, with a standard deviation of 18.971, while the control group's mean was 28.01, with a standard deviation of 13.853. The mean difference was 7.29 ($t = 281$, $p = .000$), favoring the experimental group. This shows that the smartboard, including the study approach, promoted participant success after the intervention.

A similar impact assessment was used to determine the knowledge retention of the two groups (Table 6).

Table 6: Knowledge retention for the two study groups

Group	n	Mean	Standard deviation	*t*	df	Sig(2-tailed)
Experimental	142	29.23	14.232	3.763	281	0.023
Control	142	26.72	12.673			

The mean and standard deviation (M = 29.23, SD = 14.232) of the experimental group on knowledge retention was higher than the mean and standard deviation (M = 26.72, SD = 12.673) of the control group, at a 0.023 significance level. Nevertheless, comparison of the posttest scores also revealed that both groups showed a significant decrease in means and standard deviations. The independent *t* test revealed a significant difference in knowledge retention and application, favoring the experimental group at posttest ($t = 3.763$, $p < .05$).

4. Discussion

The interventional approach in this study adds value to current studies about technology integration in teaching and learning. We applied the intervention to the two groups with different mediums of instruction. However, the topics were the same for both groups in a monitored environment. Before the intervention, the two groups were not significantly different in terms of academic performance, as shown in Table 2. The control group performed slightly better than the experimental group in the pretest, but in the posttest, the experimental group performed better. Aktas and Aydin (2016) similarly found a slight difference between two groups. Before the intervention, the control group performed better against the experimental group, but after the intervention, the experimental group performed better. Statistically, both groups had progressive improvement in performance as they moved from the pretest to the posttest. This implies that learning could be improved in any learning environment, depending on how the content was taught and prepared, resources, or students' background to learn the topics. In another study, higher academic improvement was found from pretest to posttest in the experimental group than in the control group (Mihindo et al., 2017).

In this study, we further compared the two groups on knowledge retention four weeks after the study activities, finding that the difference between the groups was statistically significant. The experimental group performed better than the control group on knowledge retention and application. Notably, the smartboard technology supported the experimental group to learn through learning objectives, which may have enabled them to retain factual knowledge after four weeks of intervention. Participants were able to understand the conceptual knowledge about the qualitative and quantitative measurement of acids and bases in this study, and it may therefore be concluded that the teaching strategy should be appropriate and interactive (Hennessy et al., 2010). According to the WAEC (2019), students found it difficult to perform well in the final examination on these topics. Research has also shown conceptual understanding and positive learning outcomes post-intervention of two different groups (Aktas & Aydin, 2016; Aldalalah, 2021; Hennessy et al., 2010). This happens because student learning in the smart classrooms is motivated by availability of facilities, such as student response systems (Cutrim, 2008) and smart learning objects (Davidovitch & Yavich, 2017; Lopez, 2010; Tekin, 2013), which may differ from the traditional classrooms. In using audio-visual teaching aids in the smartboard, Kirbas (2018) found significant improvement in students' interpretation of chemical phenomena compared to students who only used a textbook problem-solving approach. For example, the integration of PhET software into a smartboard can be used to demonstrate the mole or concentration ratio calculation by adding indicators or changing variables or the substance quantity. However, the instructional hours can be compromised (Kirbas, 2018) and the performance of students may not be as outstanding as anticipated (Higgins, 2010) if the technological knowledge is inadequate (Jammeh et al., 2022).

The evaluation of national examination results has also supported the conclusion that smartboards contribute to positive learning outcomes (Hanover Research, 2014; Ryoko & Tanya, n.d.). In terms of the mean average, students in the smart classroom had a higher average than those in the traditional classroom on the national examination (Hanover Research, 2014). Similar results were found by Moussa et al. (2020) during the comparative study on students in two different classrooms (smart technology schools and non-smart technology schools). The results showed that students in the smart technology schools obtained more passes, and the mean scores from the designed questions were also higher than in the non-smart technology schools (Moussa et al., 2020). This success could be attributed to the flexibility and interactive nature of smartboard integration (Davidovitch & Yavich 2017), particularly immediate feedback while using the smartboard (Moore, 2021).

According to Krajcik and Mun (2014) and Cutrim (2008), immediate feedback is imperative in learning and is mainly associated with the integration of clickers with the smartboard application. For example, during the formative assessment, each student's scores are projected on the smartboard, which indicates the percentage of students in the class, which is different in the non-smart classrooms (Mehtela, 2021). On the other hand, in traditional classrooms, feedback may take longer than usual, and evaluation is done on paper (Tyagi et al., 2020).

Due to the self-regulatory, adaptive, and resource-enriched nature of smartboards (Rosmansyah et al., 2022), students apply less effort to assess their conceptual understanding and application (Goodman et al., 2013). Because the smartboard coordinates the three presences in the classroom (learners, teaching, and technology) and these presences are coordinated, students are supported to perform better (Zhu et al., 2016). In educational technology applications such as smartboard integration, students have the opportunity to explore and interact (Graham, 2013) with learning objects, whereas in the traditional classroom, this aspect might be limited to physical experimentation. This convenience therefore supports the teaching and learning of qualitative and quantitative measurement and calculation of acid-base reactions, as seen in the positive reflections of students' academic performance. However, Higgins (2010) contradicted these notions in his study on the interactive whiteboard in the science classroom. He found that conceptual understanding through learning outcomes was little during students' interaction with technology. Because most of the technology applications used by teachers are under their control, students have few opportunities to use the technology (Kafyulilo et al., 2016). This implies that teachers were not practicing the purpose and functions of instructional technology, instead using technology for non-educational purposes, such as playing movies (Sorokoumova et al., 2021).

5. Conclusion

The conceptual understanding of the qualitative and quantitative calculation and measurement of acid-base reactions, which the participants found challenging, translated positively into their academic performance. The test scores of participants taught using smartboards were compared with the test scores of participants taught using traditional instructional facilities. The results revealed that the experimental group performed better than the control group. In addition, both groups showed significant improvement in the intervention from the pretest to the posttest. This implies that the condition of the teaching strategy must be effective and appropriate as it reflects positively on students' learning outcomes.

Learning by doing and seeing was one of the strategies reflected in this study which might contribute to learning retention, other than in a situation where students learn through hands-on (physical experimentation) only without audio-visual teaching aids. For example, the experimental group, who learned concepts through the smartboard, performed better in knowledge retention and application than the control group.

The results imply that smartboard integration is as important as the typical technology classroom. Based on the test scores of the two groups, we may conclude that the smartboard can improve learning in subjects other than chemistry if policymakers step up to increase the number of technological tools and continue to upgrade smart facilities in schools. The effectiveness could be further investigated if all smartboards are upgraded, and the provision of power and internet supply is consistent. There is a need for professionals, including present teachers and students, to receive technology training to be adept at using future instructional tools. Monitoring and evaluation need to be strengthened and implemented to reflect positive smartboard integration into teaching and learning.

This quasi-experimental study has provided an educative contribution to technology integration in the classroom, especially innovation in teaching and learning. It provides policymakers with insight into the technology used, processes, and the creation and growth of learning processes. Policymakers may regard the smartboard as necessary for improving curricular teaching and learning outcomes. Instructors who recognize technology as a problem-solving tool may change how they teach. Future researchers will benefit by learning about the application of technology, including not only traditional technology but also smartboards.

6. Limitations

This research involved only urban centers and Grade 11 students and can therefore be expanded to other regions and include different grades to determine the effectiveness of the smartboard in learning. As such, generalizations concerning the effects of education aided by the smartboard on a larger population can only be made after researching more extensive and diverse populations. Given the account of the study duration, the extended period of future studies may stimulate more general use and interaction.

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