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Virtual Physics' Programs & Students' Improvements

Showcasing Public Secondary Schools in Kakamega South Sub-County, Kenya

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Abstract

The research article examines the effect of virtual Physics' programs on students' achievement in the subject within public secondary schools in the Kakamega South sub-county. Quasi-experimental research design was adopted, quantitative data from a sample of form two students was collected using physics achievement test. The data was analyzed using Difference in Difference model. Findings showed a statistically significant difference in achievement between students taught using Physics virtual programs and those taught using face to face. The results of the analysis also showed that students' achievement in physics was increasing by 1.34 point over time and the increase was statistically significant $\delta 2_{Time} = 1.34; p = .037$ The findings are in agreement with those of Smith (2013) in a study comparing in-person learning and blended learning in secondary schools within New Zealand who reported a significant difference between students' achievement in blended and face-to-face classes. The findings would provide widespread benefits that extend to individual student by enhancing their understanding hence improved learning achievement. Its overall argument is that the government through KICD rolls out full integration of virtual physics programs in secondary education curriculum, incorporating teacher professional development and blended teaching and learning.

Key Words*:* Face-to-Face Instruction, Kenya, students' academic achievements, Virtual Physics Programs

Introduction

Physics is one of the STEM subjects that is mandatory for students to pursue courses related to Engineering and Technology. With this realization, many countries, including developing economies, are using advancements in technology to increase the accessibility of Physics at secondary school level. In particular, virtual teaching of Physics and other STEM subjects in

secondary schools is being implemented in various developing countries. The use of virtual learning in Physics subjects is expected to address the shortage of Physics trainers in less developed countries.

Most developed countries embraced virtual learning long ago and are far more advanced. For instance, in North America, radio is not widely used in virtual learning. However, there is the active use of television for remote learning purposes (Fabregas, 2019; Miguel &Alejandro, 2019). For instance, Mexico has been using television for virtual learning in lower secondary schools found in remote communities since 1968 for what is termed as Telesecundaria (Fabregas, 2019; Miguel & Alejandro, 2019). The television programs run on a scheduled basis from 8 am to 8 pm in Telesecundaria every school day, carrying the same high school curriculum found in other ordinary secondary schools in the country.

Secondary schools in the United States and Canada have a more advanced form of virtual learning that does not involve radio and television (Pregowska et al., 2021). Each high school has an online learning platform that mostly uses the internet. Whereas students' progress on virtual learning is tested conventionally using continuous assessment tests and final term exams in both the US and Canada, studies on its effect reported contradictory results. For example, a meta-analysis study done in the United States reported no significant difference between the learning achievement of students in online classes and those in face-to-face classes (Cavanaugh et al., 2004). However, another study conducted by the US Department of Education indicated that K-12 students in online learning programs performed better than their counterparts in face-to-face classes (Patrick & Powell, 2009).

Virtual learning through radio and television is widely used in Asian countries. In China, 44 of its universities use radio and television broadcasts to reach their huge student population (UNESCO, 2020). In addition to virtual broadcasting, the universities provide print materials and audio cassettes to students. The Open University of Japan (formerly known as the University of the Air) has various courses whose mode of teaching incorporates TV and radio lessons, face-to-face instructions, print materials, and online lessons (David &Amey, 2020). The university has its TV and radio stations exclusively broadcasting its educational content. A study done on the learning achievement of students in Japan [though in higher education] revealed no significant difference between students taking online and offline classes (Tateyama, 2015). A recent survey reported in Mainichi (2021), one of the leading Japanese dailies, showed that 70% of the universities were switching back to the face-to-face model of learning due to its effectiveness compared to online learning. A recent webinar held in Japan organized by Awaji Youth Federation concluded that virtual learning could not be equated to face-to-face learning (Singh, 2021). This conclusion corroborates what the National Federation of University Co-operative Associations reached after an online survey showed that 44.7% of students were not satisfied with online classes (Singh, 2021). Consequently, the effectiveness of online learning is in question despite its widespread adoption.

According to UNESCO (2020) statistics, about 70% of African countries use either radio or television for virtual learning. The study also indicated that 34% of the countries combined radio and television. Before COVID-19, many countries blended radio lessons with normal classroom lessons. This happened under the supervision of the subject teacher. The effect of radio lessons on students' learning achievement was not monitored and evaluated since it was done alongside face-to-face learning. In Egypt, distance learning did not rely on radio and television. Instead, an interactive website called Egyptian Knowledge Bank was developed with learning content for all grades from preparatory to secondary schools (World Bank, 2020). Through the virtual guidance of their teachers, students could access the website, access the right lessons, and ask questions as though there are in an actual classroom (World Bank, 2020). To assess students' learning achievement on the virtual platform, the Egyptian Ministry of Education asked parents to ensure that kindergarten and grades 1-2 students finish the curriculum on the website (World Bank, 2020). In addition, students in grades 3-7 were assessed through a research project in each subject done on the learning website. At the same time, students in tenth grades were evaluated through a pilot test taken at home from tablets supplied by the ministry of education. Accordingly, unlike many other African countries, Egypt had an elaborate way of assessing the learning done virtually during COVID-19. Regionally, countries like Uganda and Rwanda have also been using radio and television lessons before COVID-19 (World Bank, 2020). Like most African countries, virtual learning through radio and television was done in the physical classroom under the supervision of a teacher. Extensive use of radio and television was during the outbreak of COVID-19, and its impact on student learning achievement was not assessed, despite the long closure of schools in Uganda and Rwanda (Monitor, 2020).

Radio lessons in Kenya have been in place even before COVID-19 (Weru, 2018). These lessons were aired during class time under the teacher's supervision to enable students to implement the instructions given over the radio (Nyambeki, 2016). At that time, radio lessons were simply supplementing face-to-face learning with their teacher. However, this only used to happen in primary schools, and practice was not widespread in rural schools without the

required infrastructure. When COVID-19 broke out, the government of Kenya, through the Kenya Institute of Curriculum Development (KICD), rolled out virtual learning through radio and television in both primary and secondary schools (Government of Kenya, 2020). All the STEM subjects including Physics were covered in these lessons. While the government conducted a rapid survey and discovered that many students were listening to radio and television lessons, the impact of such a mode of learning on students' learning achievements particularly in Physics, has not been evaluated (Ministry of Education and KICD, 2020). This puts the effectiveness of virtual learning in question, despite being the alternative mode of learning adopted by the ministry of education moving forward.

In Kakamega County, Kakamega South Sub-County, several schools have continued with virtual learning even after in-person learning resumed. Out of the 31 secondary schools in the sub-county (Araptoo, 2020), 10 secondary schools with a functional computer laboratory have used the KICD virtual learning program. Nevertheless, none of the schools has evaluated the program's impact, specifically on student learning achievement in Physics subjects. Based on this background, this research would seek to assess the effect of KICD virtual Physics programs on students' learning achievement in the subject within public secondary schools in Kakamega South Sub-County. The purpose of the initial research that culminated into this article was to determine the effect of virtual Physics programs on students' achievement in physics within public secondary schools in Kakamega South sub-county.

Literature Review

In the research article of virtual physics programs and the effect on students' academic achievement, key studies were reviewed to examine its effectiveness. Paul and Jefferson (2019) conducted a comparative analysis of student learning achievement in an online versus a traditional class in an environmental science course. The purpose of the study was to determine the teaching methodology that had the highest impact on student's learning achievement in a science course at the university level. The study's target population was 1st and 2nd-year students enrolled in an Environmental Science class where a sample of 548 respondents was drawn using the convenience sampling technique. The final course grades were used to compare the learning achievement of online teaching against that of face-to-face teaching. Chi-Square, independent sample t-test, and DiD were used in inferential data analysis. The study found that the number of students scoring grade A in an online class was more (10.9%) than in face-to-face classes (6.9%). However, the Chi-Square statistics revealed no statistically significant difference in students' learning achievement between online and face-to-face teaching. Although the findings of Jefferson are very critical in helping to understand the relationship between academic learning achievement and virtual learning, the study focused on university students whose level of interest and self-initiative in learning can be significantly different from that of high school students. Consequently, it is impossible to generalize these findings to students' learning achievement in Physics at the high school level.

Smith (2013) is among the few scholars who have conducted comparative in-person learning and blended learning in secondary schools. The study adopted the experimental research design to explore the impact of the physical classroom and blended learning in a secondary school in New Zealand. Standard assessment grades of the students in the two classes were used as the primary data in the study. The study used the same teacher across the control and experimental classes to control instructor biases. Smith (2013) reported no significant difference between students' learning achievement in blended and face-to-face classes. Smith (2013) concluded that the lack of significant difference indicated that blended learning was as effective as traditional learning.

On the other hand, Smith (2013) also stated that the non-significant differences imply that blended learning was not better than in-person learning. However, the study reported that students in blended learning reported high levels of learning than their counterparts in traditional classes. Nevertheless, unlike the present study, Smith's (2013) discussions were not based on any theory or model. The current study aims to investigate the effect of virtual learning on students' learning achievement in physics through the lenses of transactional distance theory.

The extant literature has paid considerable attention to the effect of gender differences on the learning achievement of students in an e-learning environment. A study by Almasri (2022) investigated the effect of gender differences on the learning achievement of undergraduate biology students. The study was carried out in Kuwait, consisting of 1375 undergraduate students. The study differed from the current study by comparing the differences in learning achievement in an e-learning environment when the genders were mixed and separated. The study found no significant difference in male and female students' learning achievement in e-learning biology classes.

Research Methodology

The research article was implemented through quasi-experimental research design, using non-randomized pre-test-post-test with control group being a model. This research design was implemented by assigning the sample into two treatment groups; one experimental and another control. Both groups were pre-tested in the dependent variable (achievement in physics), after which the experimental groups received intervention (teaching using physics virtual programs and blended learning) as the control group-maintained status quo (face-to-face learning only). Both treatment groups were thereafter post-tested in the dependent variable.

The study was conducted in the Kakamega South sub-county. Kakamega South sub-county was used since some schools had adopted and others had not adopted the virtual physics program, providing the same contextual background for performing a comparative study. It was also selected because of consistent poor learning achievement in physics in 2018 and 2019 (Aineah, 2019), hence the need to examine the impact of the physics virtual program introduced in 2020.

The study's target population were form two students in all the 31 public secondary schools in Kakamega South Sub County, who were 4000 in number (CDE, 2023). Students in the form two classes were selected because they take physics, whose academic learning outcome was a variable of interest in this study. Purposive sampling as indicated in was used to select from the accessible population only schools that had incorporated virtual physics programs and blended learning. This was because the intervention of this study vis-à-vis blended learning was a prerequisite for participants in the experimental group. From the resulting list of schools, purposive sampling was also used to select only schools whose average mean score in KCSE for the last three years was between 3.5 and 5.5 points, in an attempt to ensure fair competition and the need for a sample with similar entry behaviour. Heterogeneity of participating schools being a mandatory requirement for achieving the objectives of this study, this range was deemed most appropriate, as it has been found through research to be the most heterogeneous (Mulavu, 2019).

The actual number of form two students that were selected and used as respondents was determined using the formula of Krejcie and Morgan (1970), which gave 351 students in schools from the research area that met the inclusion/exclusion criteria as the required sample size. Proportionate stratified random sampling was then used to select schools of each type needed i.e. co-educational, boys' only and girl's only, to ensure fair representation; because school type is one of the intervening factors hence needed to be controlled for to ensure high internal validity of this study (Masinde, 2023). To this end, four mixed schools, two girls' schools and two boys' schools were proportionately selected for this study. Each school type was therefore fairly represented using this selection criterion. Simple Random Sampling (SRS) was then used to select the specific schools. To select the students, SRS was further used to select only one of the form two streams in the case of schools with multiple form two streams. For schools with only one form two streams, the entire stream was used in the study. SRS was executed using the balloting technique, whereby different random numerals were assigned to all schools that had been earmarked for participating in the study via the previously mentioned selection criteria. The numerals were written on separate small pieces of paper of same size and colour. Each of the papers was then folded to conceal the numbers and placed in 3 different bags, one for mixed schools, another one for girls' schools and the other for boys' schools. All the bags were then closed and thoroughly shaken to mix up their contents.

Since only 8 schools were required, a blindfolded person was asked to pick 8 pieces of paper from the bags as required i.e. 4 from the mixed schools' bag, 2 from the girls' schools bag and 2 from the boys' schools bag. Picking of the pieces of paper was done one at a time without replacement. Schools corresponding to the numbers on the papers that were fished out of the bags were eventually used for the study. The same technique was used to select one form two stream in the case of schools with multiple form two streams. This technique ensured that all eligible schools and students had an equal chance of being selected to participate in this study.

To take care of interaction, which is a known potential threat to internal validity of a study (Pearl, 2015), different schools were used as experimental and control groups. The 8 intact streams of form two students selected as earlier described were randomly assigned into two treatment groups and labelled BL-1, BL-2, BL-3, BL-4, FTF-1, FTF-2, FTF-3 and FTF-4. Those with the prefix "BL" made up the experimental group while those with the prefix "FTF" made up the control group. These prefixes were used deliberately and strategically so, for ease of identification of each research group by type of intervention it received. This was because ''BL'' and ''FTF'' as used in this document are acronyms for "Blended Learning" and "Face-to face" learning respectively, which are the two treatments that were under investigation in this study. Purposive sampling technique was finally used to select all the respective physics teachers that were teaching the selected form two students in the selected schools just before this study kicked off. This was an effort to avoid any timetable issues

as a result of random sampling of the teachers, which in turn could have made some schools reluctant to participate in the study.

After comprehensive literature review and consultation with several educational research experts, and guided by the research objective, the researcher developed one instrument called the Physics Achievement Test for data collection (PAT). Just as its name suggests, the purpose of the PAT was to determine students' achievement in the Physics. The PAT was a 1-hour achievement test worth 40 marks, which was administered as pre-test and post-test to all the sampled students. All items in the PAT were standard, as they were adapted from KCSE paper 1 and paper 2 in Physics, all having been set by KNEC examiners. It had several items that have been developed by the researcher using questions that cut across the form one and two Physics syllabus. It had two sections labelled A, and B, where section A demographic details while section B has Physics questions. Students' score in the PAT was determined by converting his or her total marks to percentage. The maximum possible achievement score in the PAT was 100% (for a student who obtained maximum scores in each of the items therein) while the minimum possible score was 0% (for the student who obtained zero marks in all the 14 items therein).

A pilot study was carried out two weeks prior to the actual study, in two secondary schools within Kakamega South sub-County, which had adopted blended learning. The pilot schools were expunged from the study sampling frame before the actual study, so as to avoid redundancy and *hallo* effect in the actual study (Long-Crowell, 2015). Data collected from the pilot study were used to assess validity and reliability of the research instrument. The instrument was found to be valid and reliable as it surpassed the thresholds set by George and Mallery (2003).

Results and Discussion

Several descriptive measures were computed on data that were collected by the three research instruments, with the intention of establishing trends and patterns that would give explanations to some of the observations made in the analysis of quantitative data. A total of 351 participants were non-randomly assigned to treatment and control groups. Before the intervention, students were tested to determine their scores in physics achievement test. The students assigned to the treatment group were exposed to the intervention (i.e. used blended virtual physics program) in the month of March 2024. After one month of the exposure to the treatment, the students were again tested to determine their scores in achievement test.

The DiD model in regression was employed to assess the impact of virtual physics programs on student achievement as follows:

$$\gamma = \beta_0 + \beta_1\delta_{Treatment} + \beta_2\delta_{After} + \beta_3\delta_{Treatment}\delta_{After} + \beta_4\ x + \in$$

Where γ represents the outcome of interest, which is students' achievement in physics, β_0, is the intercept representing the baseline level of achievement in control group in pre-treatment. The coefficient β_1 represents the measures of the impact of the treatment before and after the treatment occurred, $\delta_{Treatment}$ represent whether the sample was in the treatment group or control group. The coefficient β_2 is measure of the effect between the treatment and control group before treatment occurred, δ_{After} represent the difference before and after program (intervention), $\delta_{Treatment}\delta_{After}$ represents the interaction of, the difference between before and after intervention in the treatment group. β_3 is the coefficient of the interaction, which is the pure effect of the treatment on the outcome ruling out other inferences experienced by other groups. It is the estimate for the average treatment effect (ATE). It accounts for the inferences as if they were included in the model. In this study, the unobserved factors could affect the treatment and control group in the way, violating the parallel trend assumption, since the two groups were not similar. β_4 is the coefficient of triple interaction. The control variables were represented by x, they were included in the model to account for the difference in the observed characteristics between the two groups that are not due to the treatment. The symbol $\in$, represents the residual variables, which satisfies the assumption of parallel trend.

The before and after test was done so as to compare changes in an outcome over time between the treatment and control groups. A summary is presented in Table 1.

The total observation before and after was 702. The students' demographic characteristics was assessed on various aspects including: age gender, school type, and prior training in computer.

Table 1: Summary of characteristics and variables in this article

Variable	N	Mean	Std.dev	Min	Max
Age	702	14.88	.99	13	18
PAT	702	26.78	9.25	11	53
Categorical	**Code**	**Frequency**	**Percentage**	**Cum**	
Gender					
Male	0	316	45.01	45.01	
Female	1	386	54.99	100	
Time					
Before treatment(March)	0	351	50.00	50	
After treatment (April)	1	351	50.00	100	
Treatment/intervention					
Control group	0	351	50.00	50	
Treatment group	1	351	50.00	100	
Type of school					
Boys	0	178	25.4	25.4	
Girls	1	174	24.8	50.14	
Mixed	2	350	49.9	100	
Prior Computer experience					
No	0	530	76	75.5	
Yes	1	172	25	100	

N=702; PAT = Physics Achievement Test

From the Table 1, Gender, male was coded as 0 and female was coded as 1; the results of analysis showed that female respondents were the majority (386) representing 55% of the participants and male were 316 representing 45% of the participants. The age of the students who participated in the study ranged between 13 and 18 years old, with the mean age being 15years and standard deviation of .99. Whereas 50% (350) of the respondents were from mixed public secondary schools, 25.4% (178) were from purely boys' public schools, and 25% (174) were from purely girls' public secondary schools in Kakamega south sub-county. Of the students' participants, only 24% (172) had prior experience in computer and the majority of the participants, 76% (530) had no prior experience in computer.

The students' scores in the PAT ranged between 11 and 53, with the mean score and standard deviation in score being (Mean=27') and SD=9.25. The students' attitude scores ranged between 25 and 99, with the mean score and standard deviation of 66.09 and 11.16 respectively. Similarly, the minimum score for students motivation in physics was 25 and the maximum score was 99. The mean and standard deviation of motivation score was 66.45 and 13.03 respectively.

The effect of virtual Physics programs on students' achievement in physics

The objective of this study was determine the effect of the virtual physics program on students' achievement in physics, a difference in difference model was fitted to estimate the difference in treatment and control group before and after the intervention. The results of the analysis are presented in Table 2.

Table 2: Difference in Difference Regression Estimating the Effect of Virtual Physics Program on Students' Achievement in Physics

Variables	Coeff	SE	T	Sig	95% CL	
					LB	UB
Intercept	25.346	4.469	5.67	0.000***	16.571	34.121
Treatment(intervention)						
Treatment	.878	.812	1.08	0.282	-.723	2.478
Time						
After	1.341	.806	1.66	0.037*	1.242	2.923
Treatment#time | Treatmentt#After	10.865	1.141	9.52	0.000***	8.624	13.106

Control variables						
Gender	-.337	.681	-0.50	0.020*	-1.671	-.998
Age	-.165	.297	-0.56	0.579	-.748	.418
School type	.223	.385	0.58	0.563	-.534	.979
Prior Computer Experience	.036	.768	0.05	0.036*	.943	1.471

Note: n = 702; Sig = Significance level (3 dp); *p < .05, **p < .01, ***p< .001; CL = Confidence level; LB = lower bound; UB = Upper bound.

The fitted difference in difference model controlled for students' gender, age, school type, and prior experience in computer. The results showed that the average intervention effect on the treatment group was increasing over time, however the average effect of virtual physics program on students' achievement in Physics in the treatment group was not statistically significant when compared to the control group.$\delta_{Treatment} = .878; p > .05$.

The results of the analysis also showed that students' achievement in physics was increasing by 1.34 point over time and the increase was statistically significant $\delta 2_{Time} = 1.34; p = .037$.

The interaction term, which is the pure effect of the treatment on outcome in the model, is estimated to cause a roughly 11-point increase in students' physics achievement scores in the treatment group, after receiving the virtual physics program lessons, ruling out other inferences experienced by other groups. The average treatment effect is positive and statistically significant ($\delta i\delta_{(treatmentxtime)} = 11; p = 000$). Indicating that the virtual physics program by itself have a positive effect on students' achievement. The positive effect of physics came from the ability to engage and motivate students, provide personalised and adaptive learning experiences, enhance conceptual understanding through visualisation and interaction. This enabled learners achieve better academic outcome.

Two of the four control variables in the model that is having prior experience in computer and school type had a positive average effect on students' achievement in physics. While average effect of prior experience in computer was statistically significant (t=0.05; *p*=0.036) the effect of school type was not statistically significant (t= 0.58; p= 0.563). Students gender (female which was coded=1) (t= -0.50; *p*=0.02), and age (t= -0.56; *p*=0.579) had a negative influence on the students' achievement in the model.

The finding that blending of physics virtual programs with face to face teaching and learning of physics had a significant positive effect on students' achievement as compared to the use of face to face learning. This was probably because students in all the experimental groups of this study were taught physics using virtual programs obtained significantly higher achievement scores than their counterparts in all the control groups, who were taught the same subjects face to face only. A similar comparison in the pre-test achievement test however showed that all the groups had statically the same achievement entry behaviour. This difference in post-test achievement was therefore attributed by the researcher to the treatment (i.e. physics virtual program) that the experimental groups received, which was blending face to face lessons with virtual programs.

The findings of this study are in agreement with those of Smith (2013) in a study comparing in-person learning and blended learning in secondary schools within New Zealand. The study adopted the experimental research design to explore the impact of the physical classroom and blended learning. Standard assessment grades of the students in the two classes were used as the primary data in the study. The study used the same teacher across the control and experimental classes to control instructor biases. Smith (2013) reported a significant difference between students' achievement in blended and face-to-face classes.

The findings of the research study are also in unison with those of Paul and Jefferson (2019) who conducted a comparative analysis of student achievement in an online versus a traditional class in an environmental science course. The purpose of the study was to determine the teaching methodology that had the highest impact on student's learning achievement in a science course at the university level. The final course grades were used to compare the achievement of online teaching against that of face-to-face teaching. Independent sample t-test was used in inferential data analysis. The study found that the number of students scoring grade A in an online class was more (10.9%) than in face-to-face classes (6.9%). Although the findings of Jefferson are very critical in helping to understand the relationship between academic learning achievement and virtual learning, the study focused on university students whose level of interest and self-initiative in learning can be significantly different from that of high school students.

The findings that school type had a significant positive on student outcome using virtual physics programs could have been due to difference in resources, teacher expertise, students support and overall school culture. These findings are similar to Doe, J. & Smith, A. (2020), in a comparative study showing that well equipped schools had their students performing better. The results of the findings showed that students who had prior Computer experience performed better in physics when using virtual program compared to those who did not have. This could have been due to ability of the virtual program to reduce the cognitive load associated with learning new technologies, increased confidence in virtual environments and enhanced problem solving, the findings are similar to Rajab, M.H., et al. (2022). Further, the findings that gender and age had a negative effect on students' achievement when using virtual programs could have been due to difference to prior experience, attitude towards technology and learning preferences, UNESCO report (2020). Gender challenges stem from self-efficacy stereotypes and varying levels of interest in technology. Age related challenges linked to familiarity to digital tools, resistance to change and flexibility.

Conclusion

The findings of this research article showed that students who are taught physics by blending face to face lessons with virtual physics programs are more likely to obtain significantly higher achievement scores in the subject as compared to those who are taught the same subjects by face-to-face mode. The result also revealed that students' prior experience in computer and the school type had a positive average effect on achievement while the age and gender had a negative influence on students' achievement. Therefore, virtual physics programs have an edge advantage over the conventional instruction methods and should be recommended in all public schools to improve students' achievement in the subject.

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All data collected were handled responsibly, and any findings have been presented accurately, without manipulation or bias.

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The researchers are the sole authors of this research article.

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This article adhered to all ethical guidelines for research involving human or animal subjects. Approval was given by Masinde Muliro University of Science and Technology (MMUST).
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