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The Contribution of M-Learning as a Climate Change Action

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Abstract

Aim: The study assessed the carbon dioxide (CO_2) emissions avoided through M-Learning (short message service- SMS), determined the baseline knowledge retention (KR), and evaluated M-Learning changes in KR among community health promoters (CHPs). Notably, the initial training of CHPs conducted since 2006 had never been formally assessed.

Methods: This was a cross-sectional descriptive study and the sample size, n=348 (N=1,392) was calculated through Yamane's (1967) formula at a 95% confidence interval. Pre-intervention (PRIT) and post-intervention (POIT) tests measured KR before and after M-learning in a pretest-posttest quasi-experimental design. Four selected CHPs' key training manual messages from which they had been trained were interchangeably sent in the form of SMS; once per week for 12 weeks after PRIT and before POIT. This had been preceded by a 2-week SMS/ phone trial using different health-related messages. Competence based curriculum (CBC) rubrics; exceeding expectation (EE), 80–100%); meeting expectation (ME), 65-79%; approaching expectation (AE), 50-64%) and below expectation (BE), 0–49% measured both test scores.

Results: M-Learning reduced demand by 5,348 A4 papers on the assumption that each respondent would have needed one A4 paper (page) per week for key messages which also avoided 320.9Kg CO2 that would have been generated in paper manufacture from the determination that one A4 paper manufacture is 60gm of CO2. With a 92% response rate (n=320), at PRIT (82.2%) of respondents (n=263) had BE (0-49%) KR with a mean score of 30.25% (1.21 out of 4) but at POIT it rose to 62.25% (2.49 out of 4) which was an improvement ratio of 2.1.

Conclusion: This study confirms that M-Learning is an effective KR tool and a sustainable alternative to paper-based learning, reducing CO_2 emissions. It supports integrating digital learning solutions to combat climate change and enhance training effectiveness for CHPs.

Recommendations: The County Government of Nyandarua should integrate M-Learning into official training programs for CHPs and other professionals, mandate periodic digital training sessions to reinforce knowledge retention and implement policies that reduce paper dependency in offices and learning institutions, replacing printed materials with digital alternatives. Abstract

Keywords: *Carbon dioxide, knowledge retention, competence-based curriculum (CBC), climate change, m-learning.*

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1.0: INTRODUCTION

Trainers rarely think of the climate impact that comes from the training activities. All education providers should go for the training activities, methods, and modalities that have the least carbon footprint to minimize the associated environmental impacts. Comparatively, it has been argued that digital learning has significantly low or no carbon dioxide (CO_2) generation (Davies *et al.*, 2024). Mobile phones have the potential to revolutionize healthcare training under universal health coverage (UHC), particularly among the human resource for health (HRH) as indicated by Brown and Nieminen (2017) as well as Bastawrous and Armstrong (2019). In Kenya, 91% of the population owns a mobile phone, a rate that surpasses the average for the rest of Sub-Saharan Africa (Kibuacha, 2021 & Namunwa, 2019). Incidentally, all Kenyan HRH own phones like their Zambian counterparts (Zurovac *et al.*, 2018).

Beyond healthcare training, the adoption of M-Learning is likely to provide an opportunity for addressing environmental sustainability by reducing paper usage, a significant contributor to deforestation and climate change. A significant proportion of the world's deforestation is linked to paper production. Deforestation is a precursor to climate change manifested through persistent droughts, unpredicted rain patterns, floods, loss of biodiversity, and rising disease burdens. Moreover, waste paper disposal, both in composting and burning releases CO_2 as one of the main greenhouse gases (GHGs) that causes depletion of the ozone layer, global warming, and eventually climate change (Nieves, 2025).

To sustain community health, appropriately training community health promoters (CHPs) is fundamental and the knowledge retained from such training is a measure of the effectiveness of such training (Fiorini, 2022). Paper is still widely used for training despite global technological advancements. Digitalizing training is now than ever an urgent global need. It is no longer a matter of its adoption but why it has not been adopted (Wiixt, 2024). Knowledge reinforcement measures like revision or repetition elevate knowledge retention (KR) greatly (Dewah & Mutula, 2020; Shankar *et al.*, 2019) such as when specific training information is repeatedly made available to the targeted respondents at particular intervals of time to reduce forgetfulness (Stack, 2021).

Paperless learning has not been tried among CHPs, particularly the M-Learning although some human resources for health (HRH) have been said to resist paperless systems within healthcare (Star, 2023). The entry training the CHPs have received in diverse years during recruitment since 2006 has not been evaluated formally. Besides, CHPs have no courses to reinforce that training yet 50% of new knowledge is said to "decay" within 24 hours while 90% of it is lost in 7 days (Cloke, 2023). Apart from being a climate change action, Cavintek (2025) terms paperless training as a way of preparing for the 21st century. M-learning by use of mobile phones is revolutionary and healthcare has no option owing to the overriding benefits (Masero, 2023). There are few or no relevant studies touching on KR, M-Learning, or environmental impacts among the CHPs (Grant *et al.*, 2017).

2.0: LITERATURE REVIEW

Greater return on investments (ROI) is derived from training that relies on technology (FAO, 2021). Nyambura and Sabuni (2021) find mobile technology worthwhile to invest in because persons who have mobile phones check it about 150 times daily (Stack, 2021). The exam world is more permeated by technology rapidly than before as questions continue to be whether it is the paper-based or online exams that work the best. Hypothetically, online exams would be expected to reduce the demand for papers, save time, and save financial resources although technological challenges like lack of vital digital devices and insufficient technological

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familiarity might emerge. Other issues like lack of necessary broadband also become pivotal. Rural setups might be the most affected and therefore a discrepancy exists between the rural and the urban populations. For paper-based individuals, long writing sessions may challenge those unaccustomed unlike when digital systems are used. Nevertheless, the most effective method could be the one most proficient (EDExams, 2025) with the participants and this is a great determinant as to whether the preference is for online or paper-based systems without failing to achieve the key objective of evaluating knowledge and skills (Cirrus, 2023).

Online learning lacks face-to-face interaction, isolates the learner from the trainer, and has low chances for trainer motivation besides common technological difficulties even though the benefits override paper-based learning. Online learning is flexible, convenient, cost-effective, and provide learning opportunities at the time the learner chooses. Therefore, it allows multitasking especially for the working class without resigning or absconding from duty (Cohen, 2024). However, M-Learning does not happen without some drawbacks (Dias & Victo, 2017) because mobile phones can distract despite being better than other information communication technology (ICT) devices.

Paper use is currently a global threat because of its environmental impacts. Waste paper in landfills is not below a quarter of the volumes in municipal solid wastes. About 68 million trees are cut annually to manufacture paper and associated products which causes deforestation amounting to 8 million acres of land. The use of paper globally has gone up exponentially by 400% within the last four decades or so. Advocacy against such a global threat especially on the reduction of paper use can rescind this trend by turning to software solutions as opposed to hardware choices (Melo, 2019).

Eight trees may produce about 100,000 sheets of A4 paper depending on their sizes, consume electricity amounting to 2,000kWh and release 6,000kg of CO_2 as a by-product during manufacture. Therefore, one tree will generate 12,500 A4 sheets, consume 250kWh electricity, and release 750 Kg CO_2 into the atmosphere. As such, one sheet of A4 paper would be 60gm CO_2 emission which means that a ream of paper comprising 500 sheets will generate 30 Kg of CO_2, a GHG gas during manufacture. An average office oftentimes requires 10,000 sheets of A4 paper per year which translates to 600Kg of CO_2 emissions during paper manufacture and for every tree "cut" there is a ripple effect of reducing the carbon sinks because trees are known to freshen the atmospheric air (Mathews, 2023). An A4 standard paper size with 210 mm x 297 mm (about 8.27 inches x 11.69 inches) dimensions is ISO 216. The weight of the paper depends on many factors including and not limited to the nature of the manufacturing process. While a ream of A4 paper containing 500 sheets of paper will weigh differently because of the differences in paper thickness, on average it weighs 5 pounds (about 2.27 kilograms) which means each sheet of paper weighs 4.54 grams.

The main GHG gas emitted during paper manufacture is CO_2 according to Kunak (2024) whereas each Kg of paper produced generates 3.3 Kg of CO_2. Fossil fuels used during paper manufacture also generate heavy metal emissions, dioxins, and fine particles from organochloride substances. This can be overturned by technological advancements and the improving the paper manufacturing process efficiency that reduces CO_2. Pollution sensors and devices that detect or sense gas or pollution can offer great mitigation. Beyond CO_2 increase during paper manufacture, more other GHGs such as methane (CH_4), nitrous oxide (NO_2), and sulfur dioxide (SO_2) are produced and this magnifies the climate change threats.

One of the causes of desertification is deforestation and soil erosion leading to failed crops, flooding, and the infamous GHGs. Many animals and plant species are lost to drought when

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forests and their habitats get devasted because most (70%) of land animals and plants are found in the forests. Forests release moisture into the atmosphere regulating the water cycles commonly referred to as atmospheric "rivers." Due to this, deforestation disrupts the weather patterns. Local or indigenous people and the frontline communities around forests get their livelihoods depleted because they derive their support systems from their forest neighborhoods (Pachamama Alliance, 2025). While there is also a claim that deforestation has decreased in the past few decades, catastrophic disease epidemics from emerging and re-emerging morbidities proliferate when ecosystems are disrupted because of ecological imbalances. Disease vectors, vermins, and microbes come into contact with humanity and animals, especially zoonosis when their habitats are wrecked through deforestation. Also, most medicines derived from trees and plants get threatened and become extinct due to deforestation.

Taylor (2019) asserts that for every 100 Kg of solid waste, paper accounts for 35%. Paper waste also requires transportation to the disposal sites and this has costs. More waste means more management costs and extra land for landfills as waste volumes burgeon. Worse still if paper waste is burned, more air pollution is experienced. Paper toxins get access to soil and water when paper is burned or decomposes posing a serious threat to public health. Huge budgets are required for street clean-ups whereas littered sites spoil tourists and business attractions. Rodents, insect vectors, and pathogens are harbored by waste papers. Paper has shaped the world as one of the most crucial inventions of the earth even though pulp and paper products have also become detrimental in material extraction, manufacturing, transportation, storage, and waste management. Being an energy-intensive process, pulp and paper manufacture ranks fourth globally as the largest energy consumer and accounts for 6% of industrial energy consumption. It contributes 2% of direct industrial CO_2 atmospheric release (Rio *et al.,* 2022).

Anthropogenic activities have contributed to a 50% CO_2 emission rise since the 18th-century industrial revolution while noting that Carbon Dioxide Equivalent (CO_2e) is the unit for measuring it (NASA, 2024). Measuring CO_2 facilitates its management and countries are required not only to measure their emissions but also to identify from where their emissions come from. Nations of the world agreed to reduce GHG emissions under the Paris Agreement. Every country identified country-specific nationally determined contributions (NDC) as action plans for reducing emissions. Different activities generate different levels of GHGs and each country combines emissions from various activities to get accurate estimates (UNEP, 2022). As inadequate and slow mechanisms to fight climate change are being employed, scientists have warned that time is of the essence to limit global warming to 1.5°C. The Paris Agreement settled that GHGs need to be halved within eight years noting that carbon markets would play a significant role in it (UNEP, 2021).

Community health has been around even beyond the Alma Atta declaration of 1978 despite its monumental metamorphosis all along and CHPs have solved great health problems, especially in low and middle-income countries (LMICs). Even so, gaps like lack of appropriate training continue to overstretch community health services (Brooks, 2019). KR after training CHPs is one of the expected outputs. A portion of knowledge delivered in training is forgotten but some of it still is retained in the long-term memory of the brain. Repetition can act against forgetfulness to influence KR (Richards, 2022). Short training has been found to possess a superior KR according to a South African study (Plowright, 2018) where KR increases towards the end (Quadri *et al.,* 2021). Similarly, in a Sudan study, KR was 42.5% before training but rose to 97% at the end (Draiko et. al., 2019). It has been postulated that revision at certain intervals contributes to not less than a 1.4 KR improvement ratio. Revisions also improve the speed of remembering or information retrieval because long-term memory improves by 35%

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(Ameh et. al., 2016). However, to avoid cognitive overload where the brain shuts down as the computer during the "screen saver" mode, repetitions should be limited to certain levels (Richards, 2022). On the other hand, because the primacy theory suggests that only the first words of a statement are remembered, short messages should be encouraged (Wong, 2020; Meltzer, 2021; Lavery (2023).

The entry training KR for CHPs should be the basis for new KR in line with the constructivism learning theory which confirms that learning takes place when new knowledge builds on the previous one. Learning is an active and not a passive process. Past learning makes learning different in different people because the underlying knowledge retained is usually different as exhibited by the learning outcomes (McLeod, 2024).

2.1: Conceptual Framework

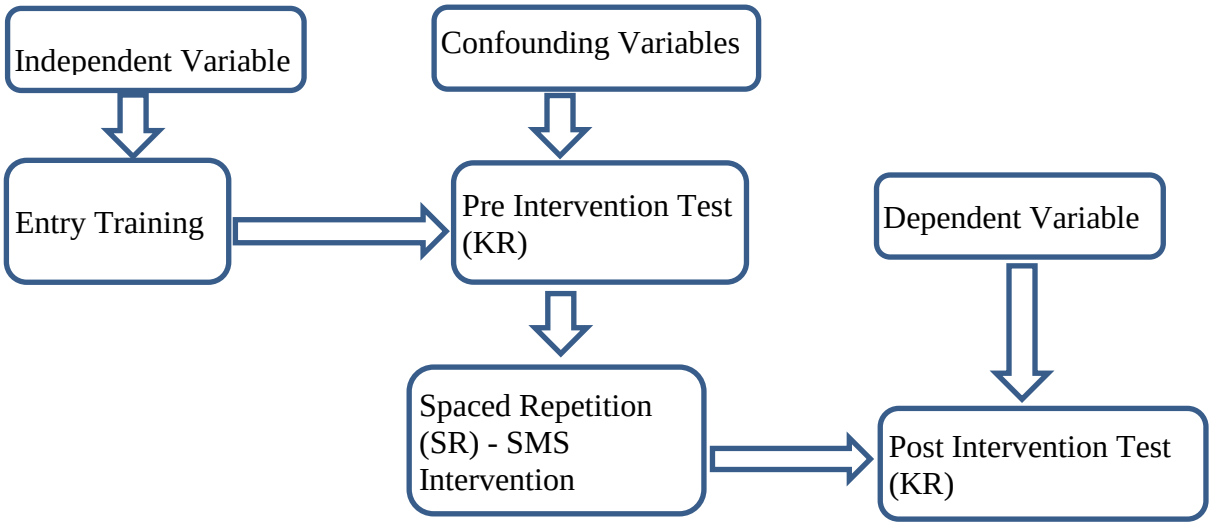

Figure 1: Conceptual Framework

Source: Researcher (2025)

3.0: METHODOLOGY:

3.1: Study Design

This was a pretest-posttest quasi-experimental design which Sreekumar (2024) says allows the collection of data before and after an intervention to track changes that are likely to occur due to that intervention. This design was preferred because it does not need randomization of any groups.

3.2: Study Location

Nyandarua County in Kenya where the study was done has been faced with some digital connectivity bottlenecks, especially in rural areas but recently efforts have been made to enable the County to benefit from fiber optic connectivity (Sabuni, 2021). According to the Nyandarua County climate change action plan of 2023-2027, the County has some perceived climate change impacts suspected to emanate from increasing environmental degradation, particularly from deforestation and pollution (County Government of Nyandarua, 2023).

3.3: Population

The study's population was the CHP workforce, N=1,392 (36.8%) retained in service. These had received the mandatory CHP entry training from the basic modules of the training manual

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that guide their community health service delivery for the communities they serve. This training formed the basis for the evaluation of this study (PRIT and POIT).

3.4: Sample and Sampling Techniques

Yamane's (1967) sample formula at a 95% confidence interval arrived at n=348 (N=1,392) desired sample size. One Community Health unit (CHU) from each of the 25 wards of the County was randomly selected together with one other unit from each of the 5 sub-counties. All 30 CHUs had a sample size (n=382) beyond the desired one (n=348) to back up data to increase statistical power and validity.

3.5: Data Collection

During the usual monthly dialogue meeting of the CHPs a census data collection was done from the 30 randomly selected CHUs. This is the study baseline- pre-intervention test (PRIT) containing 4 key content questions from the training manual of the CHPs. Then, the answers to PRIT were relayed as SMS (M-Learning) for 12 weeks to the respondents. The 4 key SMS messages were interchangeably sent once per week on the same day and time such that each message was sent 3 times in total.

At the end of the 12 weeks, and at the usual monthly dialogue meeting a repeat of the baseline test (now post-intervention test- POIT) was conducted and data from both tests was recorded for each respondent. The actual SMS for the study had been preceded by a two-week SMS/ mobile phone trial/ testing before PRIT which had different but healthy messages from the actual ones.

3.6: Statistical Analysis

To estimate the CO_2 avoided by the M-Learnig in Microsoft Excel, an emission factor of 60gm CO_2 per one A4 sheet of paper was used by multiplying the number of A4 sheets (n=5,348) that would have been used to relay the same message carried by the SMS (M-Learning) for 12 weeks preceded by the 2 weeks for SMS/ Phone trial according to Mathews (2023) formula (Figure 2). The same Microsoft Excel calculated the cost of avoided A4 papers at Ksh 900 per ream- 500 A4 paper sheets (Figure 3).

Wilcoxon signed rank sum test was used through the SPSS computer package to analyze both tests (PIT and POIT) after data verification, cleaning, and coding. Webb (2024) recommends the Wilcoxon signed rank sum test for comparing two test data sets from the same respondents especially when a change of the two sets of data is being investigated and when data is ordinal or ranked. Diagrams, figures, and tables presented data.

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4.0: FINDINGS

4.1: Assess CO_2 Emission Avoided Through M-Learning

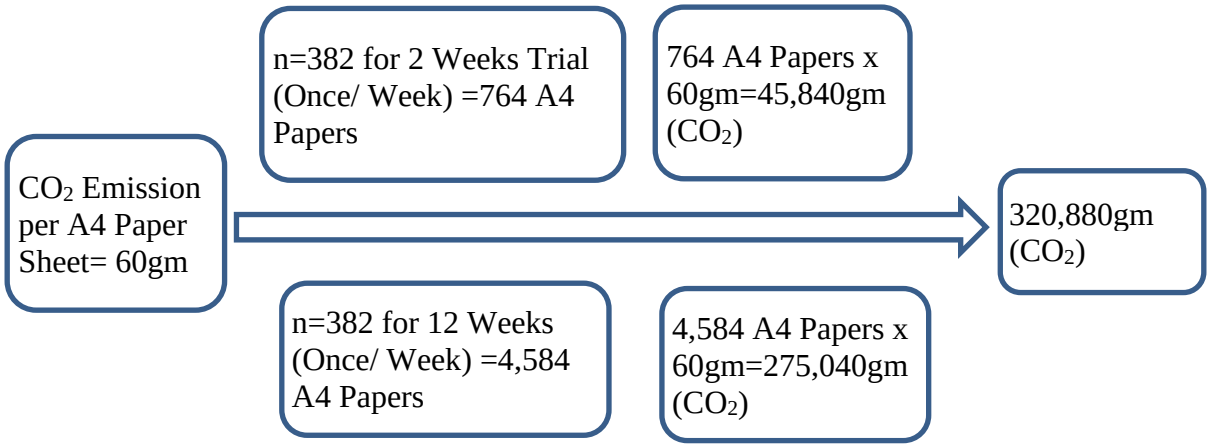

Figure 2: Total CO_2 Emission Avoided Through M-Learning

Figure 2 indicates that by avoiding paper training and opting for M-Learning (SMS) Training, the Demand for A4 Paper manufacture that would have been used went down by 5,348 Papers (10.7 Reams at 500 A4 Paper sheets per ream). This Prevented 320.9Kg CO2 emission during manufacture at 60gm CO2 emission factor for every A4 paper that would have been used in 14 weeks according to Mathews' (2023) formula. The 14 weeks entail 12 weeks of study SMS and 2 weeks of SMS/ Phone Trials. The source of formula was Mathews (2023).

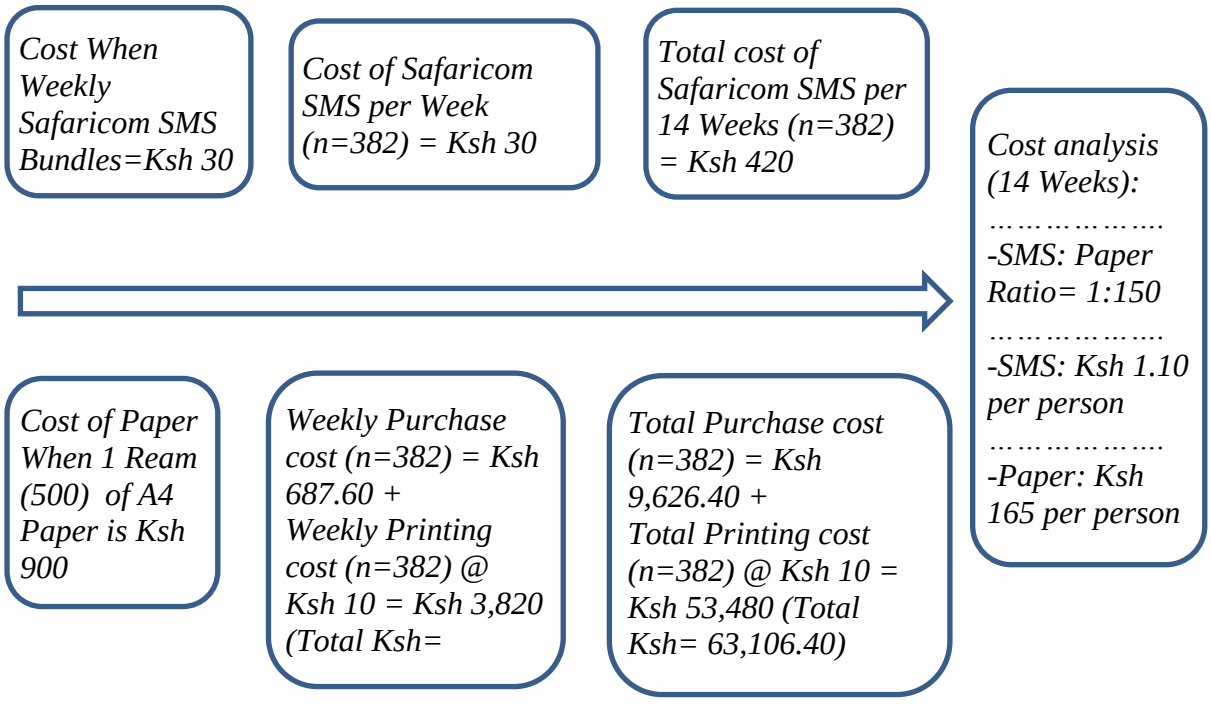

Figure 3: M-Learning (SMS) Cost Supremacy over Paper Training

Figure 3 indicates that paper training was 150 times more expensive to administer compared to m-learning (SMS) training. It cost Ksh 1.10 per respondent for the 14 weeks SMS but it

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would have cost Ksh 165 per respondent if A4 papers were used to relay the same messages assuming that each respondent would use one page of A4 to receive key messages. That is when the weekly cost of weekly bulk Safaricom SMS was Ksh 30 and the price of 500 A4 paper sheets (ream) was Ksh 900.

4.2: Determine Baseline Knowledge Retention (KR) for CHPs from their Entry Training

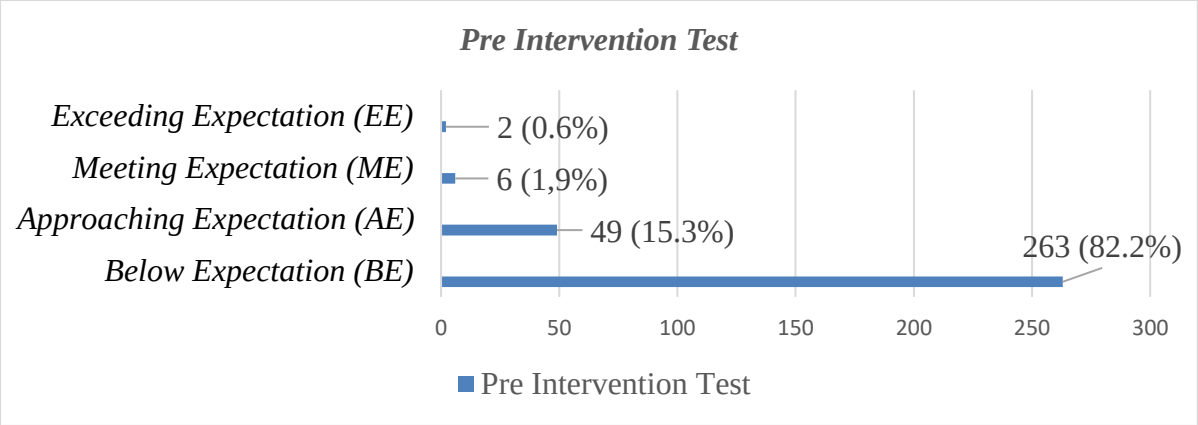

Figure 4: Pre-Intervention Test (PIT) Results

Source: Researcher (2025).

Figure 4 shows that the majority, n= 263 (82.2%) of CHPs had their knowledge retention below expectation, BE; (0- 49%).

Table 1: Mean of Pre- Intervention Test (PRIT) Results

Parameter	N	Mean	Min.	Max.	Median	Std. Dev.
Pre-test	320	1.21	1	4	1.00	.491
%	92	30.25				

Source: Researcher (2025).

Table 4 shows that the mean knowledge retention for the CHPs was below expectation (1.21 out of 4) at PRIT. That is 30.25%; BE; (0- 49%).

4.3: Evaluate Knowledge Retention Change Occasioned by M-Learning.

Table 2: Mean of Pre-Intervention (PRIT) and post Intervention Test (PIT) Results

Parameter	N	Mean	Min.	Max.	Median	Std. Dev.
Pre-test	320	1.21	1	4	1.00	.491
Average		1.85	1		2	1.384
Post-test	320	2.49	1	4	3.00	1.278

Source: Researcher (2025).

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Table 2 indicates that the mean knowledge retention increased from below expectation- BE (1.21) which was 30.25% at PRIT to approaching expectation (AE) of 2.49 (62.25%) at POIT after the 12 weeks of M-learning (SMS).

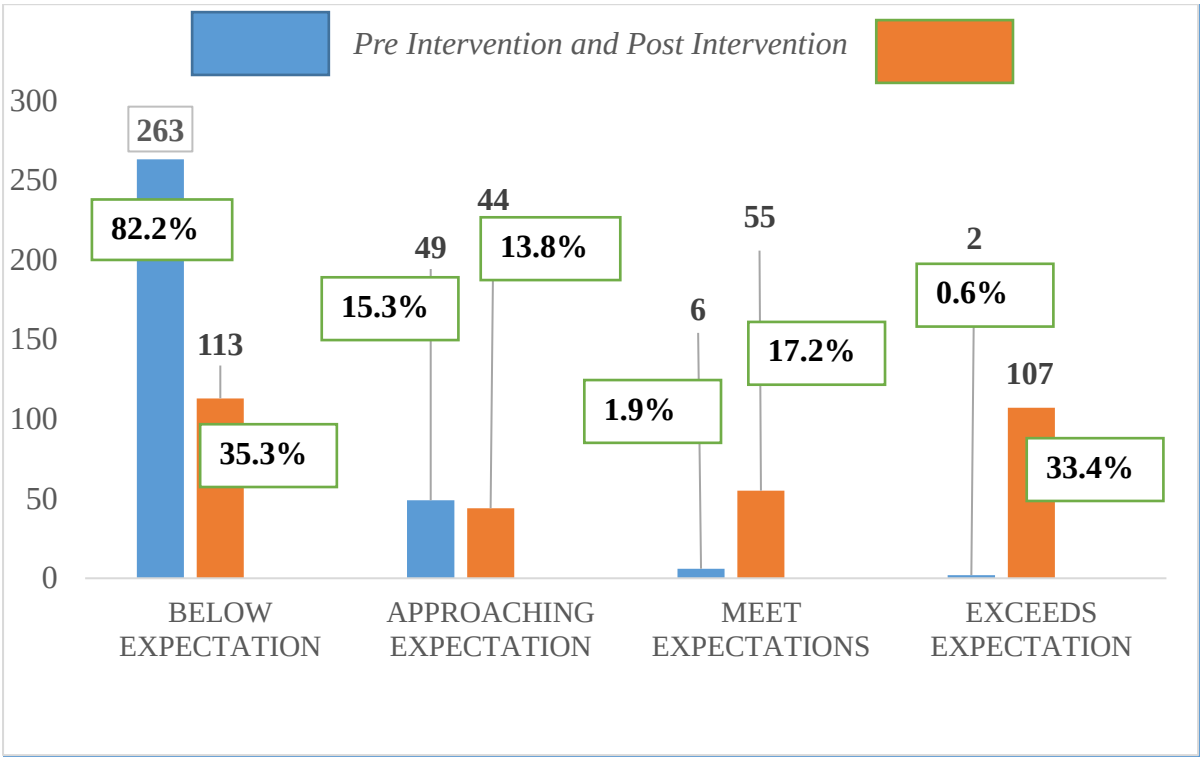

Figure 5: Pre Intervention (PRIT) and Post Intervention (POIT) Tests' Knowledge Retention.

Source: Researcher (2025).

Figure 5 indicates a knowledge retention plateau at the Approaching and Meeting Expectations (AE & ME) as knowledge retention reduces at Below expectation (BE) but increases at the Exceeding Expectation after the M-learning.

Table 3: Comparison between pre-intervention and Post-intervention Tests

	Mean (M)	Gap	% Increase	% Difference	Improvement Ratio
Pre-Intervention Teat (PRIT)	1.21 (30.25%)				
Post-Intervention Teat (POIT)	1.85 (47.25%)	1.28 (30%)	106	52	2.1
	2.49 (62.25%)				

Source: Researcher (2025).

Table 3 indicates that 106% was the percentage increase with an improvement ratio of 2.1 and a percentage difference of 52% from PRIT and POIT.

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5.0: DISCUSSION

M-Learning of this study reduced the A4 paper demand by 5,348 sheets in the assumption that each respondent would have needed one A4 paper per day to receive the key training messages. This translates to Ksh 9,626.40 for paper purchasing when each ream (500 A4 sheets) costs Ksh 900 and Ksh 53,480 for one-page paper printing (Ksh 10 per page). Moreover, 320.9 Kg CO_2 GHG which would have been released into the atmosphere by the said number of papers during manufacture was avoided when the paper learning was replaced by M-Learning (Diagrams 4.1.2 and 4.1.1). This seems to validate the argument by Nieves (2025) that M-Learning is likely to provide an opportunity to address environmental sustainability by reducing paper usage. It qualifies Wiixt's (2024) emphasis that using digitalization in training has become an urgent need and it is no longer a question of whether it will be adopted or not but why it has not been adopted going by the benefits exhibited by this M-Learning study. As a result, the world should not be torn between online and paper-use training (Cirrus, 2023) because the environmental impact of training through papers is a real global threat as confirmed by Melo (2019).

According to Mathews' (2023) formula, an average office uses 10,000 sheets of A4 paper annually which means an emission of 600 Kg of CO_2. Assuming each of the 10 departments (each headed by a county executive member- CECM) as an office in the County government of Nyandarua requires such at the minimum, then all these offices (departments) need 100,000 (200 reams of 500 sheets each) A4 sheets. While one A4 sheet generates 60 gm of CO_2 during its manufacture, then 6,000,000 gm (6,000 Kg) of CO_2 is released into the atmosphere every year due to these offices' demand for A4 sheet papers. No wonder it has already been confirmed by the County government of Nyandarua that some perceived climate change impacts have been confirmed (County Government of Nyandarua, 2023). This further qualifies the suggestion by UNEP (2021) that there are inadequate and slow mechanisms to fight climate change as scientists warn that time for fighting global warming is of the essence now that the Paris Agreement settled that GHGs are required to be halved within eight years (UNEP, 2021).

Now that Fiorini (2022) suggested that KR from training is a measure of learning effectiveness, it is imperative to say that the effectiveness of the entry training the CHPs had initially received was only below expectation- BE (30.25%) (Table 4.2.1**)** effective. Therefore, the argument by Brooke (2019) that among the CHPs training gaps existed, and as Richards (2022) reports, not every training information is retained except with repetition or revision points to a truth. The claim by Star (2023) that HRH resists paperlessness in healthcare was not perceived in this study because the respondents responded well to M-learning all along without hitches.

That knowledge reinforcement (SMS) can elevate the retention of the training knowledge as postulated by Dewah and Mutula (2020) together with Shankar *et al*. (2019) holds water going by the increase in KR which was 2.1 improvement ratio (Table 3) and echoes the idea of Stack (2021) that repetition or revision can reduce or eliminate forgetfulness. The improvement ratio, which was derived after the POIT scores were divided by the PRIT scores means that the superiority of the POIT, which is an indicator of M-Learning was 2.1 times higher. The improvement ratio was therefore comparable between the two tests. Further, it is positive that mobile phones can revolutionize healthcare training under universal health coverage (UHC), particularly among the human resource for health (HRH) as indicated by Brown and Nieminen (2017) as well as Bastawrous and Armstrong (2019). It reiterates the statement by FAO (2021) that training relying on technology has a greater ROI.

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The argument by Plowright (2018) that KR is superior when the training is shorter may hold some water but it was not determinable whether the M-Learning output would have been the same if it was shorter or longer than the scheduled 12 weeks. It was not possible to confirm Quadri et. al.'s (2021) affirmation that KR increases at the end of training because the measurement used was just at one point in time among the two tests which missed the middle series of the progression. Although Richards (2022) noticed that when repetitions are more, the mind is likely to shut down, no such indications were detected because there was no comparative data. At the same time, Meltzer (2021) and Lavery (2023) also asserted that only the first words in a statement are likely to be remembered though this was also not measurable because of the nonavailability of comparative data. Given these future studies on KR should focus on a longitudinal approach with multiple KR measurements. Future research should also look into the entire paper cradle-to-grave CO_2 emissions because this study restricted itself to the CO_2 generated at the manufacturing point only.

6.0: CONCLUSION

This study confirms that M-learning is an effective tool for reinforcing KR because the respondents improved their KR some 2.1 times after its implementation. Besides most and sometimes all HRH own a mobile phone which may be used for training them without initial phone procurement costs. Also, M-learning is a sustainable alternative to paper-based learning, reducing CO_2 emissions because the short 14 weeks with only a few respondents resulted in the evasion of 320.9 Kg CO_2 and yet it had a high (2.1) improvement ratio. M-learning integration is a probable and feasible tool for supporting digital learning solutions in order to combat climate change and enhance training effectiveness for CHPs because the CO_2 and other GHGs must be halved according to the international Paris Climate Change Agreement.

7.0: RECOMMENDATIONS

The County government of Nyandarua should integrate M-learning into official training programs for CHPs and other professionals, employ periodic digital training sessions to reinforce KR, develop mobile phone-friendly training modules for CHPs, provide incentives for paperless training, and pilot M-learning initiatives across multiple departments. The County government of Nyandarua should also shift to digital document management systems and online reporting tools in place of paper-based systems, develop and implement policies that reduce paper dependence in offices and learning institutions to replace printed materials with digital alternatives, and conduct M-learning awareness campaigns to support the transition from paper-based to digital systems.

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Conflict of Interest

The authors declare no conflict of interest.

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Ethical Approvals

This study received approvals from the National Commission of Science, Technology, and Innovation (NACOSTI), *Ref No. 728874*, and permissions from the Department of Health, County government of Nyandarua, Kenya where the study was conducted.

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