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An 89% solution adoption rate at a two-year follow-up: evaluating the effectiveness of an animated agricultural video approach

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ABSTRACT

Securing the adoption of scalable agro-educational information and communication technology (ICT) solutions by farmers remains one of the international development community's most elusive goals – in part due to two key gaps in the data: (1) limited comparisons of competing knowledge-delivery methods, and (2) few to no follow-ups on long-term knowledge retention and solution adoption. Addressing both of these gaps, this follow-up study measures farmer knowledge retention and solution adoption two years after being trained on an improved postharvest bean storage method in northern Mozambique. The results found animated-video knowledge delivery at least as effective as a traditional extension approach for knowledge retention (97.9%) and solution adoption (89%). As animated video can more cost-effectively reach the widest – even geographically isolated – populations, it readily complements extension services and international development community efforts to secure knowledge transfer and recipient buy-in for innovations. Implications and future research for adult learning are also discussed.

KEYWORDS

Adoption and diffusion of IT and rate of uptake; development issues; scalable infrastructures for development; development Issues; sustainable development in developing and transition economies; development issues

Significance statement

This research demonstrates an effective and cost-efficient animated video strategy for securing long-term knowledge retention and increased solution uptake by solution recipients. At a two-year follow-up assessment of prior training, participant knowledge retention of the steps required for preparing and using an improved postharvest bean storage system was 97.9%, while the adoption rate for the improved storage method was 89%. Among the 104 participants, a total of 96 (92.3%) also reported telling an average 8.49 other farmers about the postharvest bean storage technique, while a total of 57 (54.8%) reported demonstrating the technique to an average 6.35 others.

1. Introduction

For the international development community, to develop and deploy scalable educational solutions with reliably high potential for adoption by target populations has remained an elusive goal. While

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much research explores such knowledge delivery using information and communication technologies (ICTs) – including video animation delivered via smartphones or tablets for scaling up the diffusion of messages (Bello-Bravo & Pittendrigh, 2018; Bello-Bravo, Diaz, Venugopal, Viswanathan, & Pittendrigh, 2010; Chapman & Slaymaker, 2002) – data from this research are generally limited by three factors: (1) when studies do not quantitatively compare the use of ICTs to more traditional (extension agent) educational content delivery methods, (2) when studies do not investigate long-term knowledge retention and/or solution adoption after an initial solution or innovation training, and (3) when follow-up studies insufficiently account for, or problematize, participant 'reinvention' – where 'reinvention' refers to any (potentially beneficial, neutral or detrimental) divergence from, or enhancement to, a proposed solution that participants adopt in their process of using and/or engaging with the solution. Although reinvention typically involves participants changing an offered solution to suit their own experiences and beliefs in its local setting, it can be counted as a failure for the knowledge-delivery system used, inasmuch as participants did not take up the offered solution exactly as described or proposed.

This follow-up study addresses the first two of the above data gaps and measures knowledge retention and solution adoption by farmers in Gurúè District, Mozambique two years after quantitatively comparing the training effectiveness of an animated-video approach ('mobile ESD') versus a traditional (extension-led) knowledge-transfer approach. The innovation and solution curriculum offered in that previous training involved a scientifically grounded postharvest bean storage method using jerrycans to better secure stored beans for use by farmers in future crop planting.

1.1. Mobile education for sustainable development ('mobile ESD') and innovation diffusion in Mozambique

In Mozambique, as in most African countries, smallholder farmers constitute the majority producers of agricultural food (Kassie, Jaleta, Shiferaw, Mmbando, & Mekuria, 2012). Indeed, agriculture comprises a major portion of Mozambique's economy. Mucavele (2013) estimated that approximately 90% of rural Mozambican households engage in agriculture, with maize and cassava as two largest and most important staple crops (Day et al., 2017; Tschirley & Weber, 1994). Due to land pressure and droughts that can affect crop yields, Cunguara, Langyintuo, and Darnhofer (2011) have further highlighted how nonfarm activities are necessary to offset such losses of food and income.

While a healthy agriculture sector directly affects development, the sector also faces several critical challenges around food security, poverty alleviation, and secure livelihoods. The lingering effects of Mozambique's civil war, worsening climate change impacts, institutional limitations, and potential new threats from the expanding fall armyworm predation of maize throughout sub-Saharan Africa add to these challenges (Brück, 2004; Day et al., 2017; Mango, Siziba, & Makate, 2017; Osbahr, Twyman, Adger, & Thomas, 2008; Tschirley & Weber, 1994).

One of the most impactful and widespread challenges to Mozambique's agricultural sector is the limited number of educational extension agents available to transfer knowledge to the much larger numbers of farmers in need of extension services. As such, the sort of general and severe shortfall of agricultural extension agents for distributing such information noted by Mur, Williams, Danielsen, Audet-Bélanger, and Mulema (2015) drastically restricts knowledge transfer. The problem, however, is not only numerical; geographic remoteness – along with educational, linguistic, and gender/cultural differences – interpose further barriers to the already challenging task of eliciting solution adoption and behavior change from people (Davis, 2008; Gemo & Rivera, 2001; Karubanga, Kibwika, Sseguya, & Okry, 2017; Manfre et al., 2013).

While Mozambique has shown both a long-term commitment to a renewed, national-level pluralistic extension effort (Gemo & Rivera, 2001) as well as recent, uniquely successful applications of conservation farming approaches (Mango et al., 2017), the country's national budgetary constraints, and the necessary expansion of extension services required to effectively lower access barriers to finally reach the majority of smallholders most in need of such services, seem to preclude reaching this goal. Cunguara and Moder (2011), moreover, have noted that while extension services have increased farm income by 12%, extension services have generally been more accessible only to already comparatively wealthier farms, thus potentially contributing to wealth inequality rather than poverty alleviation.

As a complement to any ongoing extension services efforts, beginning roughly in the 1990s, information and communication technologies (ICTs) have demonstrated a capacity for ameliorating some of these numerical and resource obstacles to extension service delivery, thus affording more farmers access to critical agricultural information than previously (Asenso-Okyere & Mekonnen, 2012; Bentley, Chowdhury, & David, 2015; Bertus, Nederlof, & Heemskerk, 2007; Sseguya, Mazur, Abbott, & Matsiko, 2012; Van Mele et al., 2010). In part, this is due to the highly cost-effective leveraging of rapidly expanding digital infrastructures across Africa that ICTs can utilize (Aker, 2010; Aker & Mbiti, 2010; Bello-Bravo & Pittendrigh, 2018; Bello-Bravo, Lovett, & Pittendrigh, 2015; Gakuru, Winters, & Stepman, 2009; Herselman, 2003; Hudson, Leclair, Pelletier, & Sullivan, 2017; Tata & McNamara, 2018). While there is little dispute that research has identified a tremendous potential in ICTs for delivering much-needed knowledge to agricultural actors, including to more vulnerable or marginalized populations (Aker, 2010; Bentley, Van Mele, Harun-Ar-Rashid, & Krupnik, 2016; Bertus et al., 2007), how to most effectively and appropriately deliver such information remains an open question (Cai & Abbott, 2013; Duncombe, 2016; Van Mele et al., 2010).

Anticipating Bentley et al. (2016), who highlighted the potential of video ICT for reaching vulnerable populations – including women, youth, and the rural poor – Scientific Animation Without Borders (SAWBO) since 2010 has been developing and refining ‘mobile ESD’: an educational ICT video approach able to effectively deliver critical and scientifically grounded best-practices approaches and education for sustainable development (ESD) to diverse communities (Bello-Bravo & Pittendrigh, 2018; Bello-Bravo et al., 2010; Bello-Bravo et al., 2020). Developed in collaboration with global and local expert knowledge holders on topics concerning agricultural, health, and socioeconomic challenges facing communities around the world (but especially in Africa), each mobile ESD video produced by SAWBO combines evidence-based, aesthetically appealing animated video imagery with dialectically localized audio overdubs in the intended recipients’ most comfortable, everyday language (Bello-Bravo & Lutomia, 2016; Bello-Bravo, Olana, Enyadne, & Pittendrigh, 2013). Delivered via ICT, most often on video-enabled cellphones, this mobile ESD approach has demonstrated a comparatively greater capacity for knowledge transfer, learning gains, and motivation for buy-in or solution uptake over other forms of traditional or ICT extension knowledge delivery (Bello-Bravo, Lutomia, & Pittendrigh, 2019; Bello-Bravo, Tamò, Dannon, & Pittendrigh, 2018).

Most importantly, research shows that mobile ESD affords these gains regardless of participants’ educational or technological literacy, gender, socioeconomic status, or geographic remoteness (Bello-Bravo et al., 2020; Bello-Bravo, Zakari, Baoua, & Pittendrigh, 2018). In this way, mobile ESD has a unique capacity for most widely, scalably, and cost-effectively reaching the widest array of people but, most importantly, those most vulnerable populations (women, youth, and/or the rural poor) otherwise least likely to receive needed agricultural extension knowledge. Women often constitute an important percentage, if not the majority, of postharvest crop distributors (Bello-Bravo, Lutomia, Njoroge, & Pittendrigh, 2019). Delivering critical agriculture extension knowledge to women therefore can maximally leverage extension efforts and promises the most wide-ranging outcomes and impacts for local and national economic sustainability (Bello-Bravo et al., 2020). It also potentially reduces gendered social inequalities (Cai, Abbott, & Bwambale, 2013).

The immense promise of ICTs to deliver ESD curricula builds upon research to date that has sought to identify factors influencing long-term solution uptake of ESD content. While Rogers (1962) foundationally conceptualized knowledge diffusion as a phenomenon, considerable subsequent research has sought to characterize the influences and motivators for uptake, adoption, buy-in, and/or behavior change around diffused solutions (see Knowler & Bradshaw, 2007; Pannell, Marshall, Curtis, Vanclay, & Wilkinson, 2006). More recent work by Douthwaite and Hoffecker (2017) offers a model for making the complexity of these processes more clear and highlights the scaling of outcomes as also crucially needed as part of any solution adoption by participants.

1.2. Previous mobile ESD innovation in Mozambique: postharvest inventory storage using jerrycans

Although generalized models of ESD curriculum adoption are useful, Schmidt, Stiefel, and Hürlimann (1997) highlighted how successful diffusion of new or recommended practices are highly dependent on several other key factors: (1) the degree of local involvement in identifying the innovation needed and its possible solutions, (2) the level of perceived need for the innovation by local farmers, (3) the extent to which the solution proposed is easily available and affordable, (4) efficacy of the innovation for actually resolving the perceived problem, and (5) the opportunity to receive information about the innovation in one's own dialect using an effective delivery channel.

This study follows-up on research conducted in 2015 that trained 314 farmers in ten communities in Gurúè district in northern Mozambique in a postharvest innovation technique using plastic jerrycans to more securely and hermetically store beans. Prior to that 2015 research, focus groups with farmers in the study area found that farmers were unable to reliably find good quality bean seed to buy for future planting and had to save seed from one harvest for the next. However, they also reported also losing a substantial percentage of any stored beans to bruchids during postharvest storage. This prompted a search to develop a locally feasible improvement for postharvest bean storage. Several methods were considered, including triple bagging (sealing beans within three plastic bags, two of which are airtight) and the use of jerrycans to hermetically seal beans. However, because farmers only needed to preserve enough seed for the next planting, and because only relatively small areas of beans are typically planted, the volume of seed needed to be stored was comparatively small and could be accommodated by as little as one or two standard jerrycans (10- or 20-liter leak-proof plastic containers); moreover, most households already had at least one such plastic jerrycan. In contrast, while triple bags could store up to 100 kg, far more than farmers needed for seed, they also were not readily available locally at the time. Consequently, from this work with local farmers, the research team chose preparing and using a jerrycan for more secure postharvest bean storage as its ESD curricular content.

Farmers who learned about the jerrycan method also test-stored beans in jerrycans for six months as part of their training. After six months, they met with the research team to open the jerrycans and inspect the results and found that the sealed beans were in very good condition and showed minimal damage compared to seeds stored in unsealed plastic containers. This 'proof of concept' was important for convincing participants about the effectiveness of the jerrycan method.

2. Materials and methods

2.1. Prior study findings relevant to this follow-up

Previous research in 2015 used a structured questionnaire to collect primary socioeconomic household data – including demographics and growing and crop marketing practices for local beans – for 314 farmers in ten communities in Gurúè District in northern Mozambique. All findings and details cited below in this section are taken from that prior study.

Participants were randomly assigned to one of four experimental groups: (1) animated video ESD content delivery alone ('mobile ESD'), (2) extension agent-led lecture/demonstration of the ESD content alone ('traditional'), (3) 'traditional' delivery followed by 'mobile ESD,' and (4) 'mobile ESD' followed by 'traditional' delivery. All participants were first pre-tested on knowledge points relevant to the proposed ESD content – namely, the preparation and use of hermetically sealed jerrycans to more securely store postharvest beans; a mobile ESD approach that had been developed in part through consultation with local farmers and in light of their needs – and then on four major potential benefits of this hermetically sealed jerrycan approach. The four major potential benefits included: (1) protecting beans from insects, (2) maintaining the quality of stored beans, (3) preventing moisture from damaging beans, and (4) storing beans until bean market prices rise. On the pretest, farmers on average identified only 12% (0.48 points of 4) of the potential major benefits. Overall, two-thirds of the participants had never heard of this ESD jerrycan storage strategy technique before; one quarter had heard about it, but did not use it or know any details about it, while 6.7% were already using it.

Participants in each of the four experimental groups then received ESD-delivered curriculum with respect both to (1) the potential major benefits of the mobile ESD jerrycan method and (2) the eight steps described in the curriculum for securely preparing and storing postharvest beans in hermetically sealed jerrycans. After training, farmers from each group were invited to come forward and demonstrate what they had learned by actually filling and sealing a jerrycan.

Farmers then were post-tested on the four potential major benefits and eight curricular preparation items for the jerrycan method. For the potential major benefits, while all four experimental groups showed statistically significant improvement (see Table 1) – with an increase from the overall pretest average of 0.48 to 2.29 post-test – a Scheffe statistical test indicated that delivery method 2 ('traditional' only) showed significantly less learning than the other three delivery methods. That is, 'mobile ESD' alone, or in conjunction with a 'traditional' delivery method, resulted in statistically significant greater post-test awareness by farmers with respect to the potential benefits of the jerrycan method. Farmers were also post-tested on knowledge transfer (learning gains) for the eight knowledge items relating to the specific steps needed to prepare and seal the beans in jerrycans and the length of time beans can be stored safely for seed and to eat; all knowledge-delivery approaches showed statistically significant learning gains on the eight items.

2.2. Follow-up study (2017)

In 2017, this follow-up measured knowledge retention by repeating the original post-testing (without any refresher or additional training). We were able to consult with community leaders in six of the original ten communities in northern Mozambique in order to obtain access to as many of the original study participants as possible. Of the original 181 participants in these six areas, 104 were available for follow-up. Table 2 summarizes and compares the specific locations and numbers of participants by area across both studies.

For this follow-up, farmers were first asked to recall all of the original eight steps for storing beans. If a step was omitted, they were prompted with a question like, 'Anything else important to preparing beans?' Correct answers from either the unaided or prompted responses were counted as correct. Farmers were also asked if they used the mobile ESD jerrycan technique (and if so, how often), and whether they had described or demonstrated the technique to other farmers (and if so, how many times). Farmers were also asked open-ended, free response questions about the condition of the beans when jerrycans were later opened and about their perceptions (if any) why the jerrycan method is effective.

Table 1. Comparison by knowledge delivery type for 2015 initial knowledge and post-training knowledge of potential benefits around mobile ESD jerrycan storage.

Experimental group	Pre-test	Post-test	Df	*t*-value	*p* value
(1) Mobile ESD only	0.43	2.34	87	13.58	.000
(2) Traditional only	0.40	2.02	120	15.03	.000
(3) Traditional then mobile ESD	0.76	2.44	46	7.18	.000
(4) Mobile ESD then traditional	0.51	2.67	46	14.85	.000
Overall	0.48	2.29	313	24.85	.000

Table 2. Numbers and locations of participants in six of ten 2015/2017 study sites.

	Number of participants		
Region / Village	2015	2017	% retained
Tetete			
Tetete Sede	27	19	70.4
Tetete Sede Nova	12	8	66.7
Tetete Napuatchi	27	17	63.0
Mepuagiua			
Mepuagiua Mogeia	37	27	73.0
Mepuagiua Hulane	39	21	53.8
Mepuagiua Invacula	39	12	30.8
Total	181	104	57.4

For data analysis, ANCOVA was performed on the total re-administered, 8-item post-test scores using age, sex, interviewer, total kilograms of beans harvested in both seasons, and total bean hectares planted in both season as a covariance, respectively (see Results below). In 2015, the researchers also collected educational level data for the original 314 participants; data for 3 were not available, while only 10 of the remaining 311 had an educational level higher than seventh grade. Comparing those with less than a fifth grade education ($n = 232$) to those with a fifth or higher grade education ($n = 79$), no statistically significant relationship was found between educational level and mean correct answers on the 8-item post-test (7.25 and 7.43, respectively; $F = 2.35$, $p = .13$). While these results support the idea that mobile ESD delivery is appropriate for people of any educational level, during this follow-up, data on educational level could not be obtained. Any interaction between educational level and long-term knowledge retention and/or adoption remains to be researched.

3. Results

Farmers ($n = 104$) from six of the original ten different communities in northern Mozambique, Tetete ($n = 44$) and Mepuagiua ($n = 60$), were re-tested in 2017; 64 (61.6%) were male and 40 (38.5%) were female. Average age was 43.3 (ranging from 19 to 66). Of these, 95 (91.3%) reported they had used the postharvest jerrycan method at least once; 93 (89.4%) said they had used the technique more than once, a strong indicator of adoption. Only 6 (5.8%) reported never using the method. Among the 104 participants overall, 96 (92.3%) also reported telling an average 8.49 other farmers about the postharvest bean storage technique, while 57 (54.8%) reported demonstrating the technique to an average 6.35 others.

Table 3. Post-test 8-item knowledge test results in 2015 and 2017 re-test.

	Post-test% Correct	
Knowledge Test Item	2015($n =$ 314)	2017($n =$ 104)
Dry the beans very well before putting in the can	93.0	100
Remove pebbles and broken beans	91.1	99.0
Ensure the jerrycan is clean and dry	85.0	97.1
Fill the jerrycan completely with beans, shaking it to ensure there is no space to circulate air inside	96.5	94.1
Use an additional piece of plastic by placing it under the jerrycan cap to ensure it is securely sealed so that oxygen cannot enter the jerrycan	90.9	99.0
Once sealed, do not open the jerrycan until ready to use	90.1	97.1
Beans can be stored in the jerrycan for up to six months and then used as seed for sowing	92.3	96.9
For food, the beans can be retained longer, up to several years.	91.7	100
Average	91.3	97.9

Table 4. Comparison by delivery method for 8-item post-test score for 2015 and 2017.

	2015 Post-test		2017 Re-test*	
Experimental Treatment Group	Number	Mean score	Number	Mean Score
Traditional only	121	7.19	39	7.72
Mobile ESD only	88	7.45	21	7.48
Combination of both Methods	105	7.27	44	7.77
Overall	314	7.29	104	7.69

*$F = 1.10$, $p = 0.324$.

Table 5. Comparison by sex for 8-item post-test score for 2015 and 2017.

	2015 Post-test		2017 Re-test*	
Gender	Number	Mean score	Number	Mean score
Males	174	7.35	64	7.70
Females	140	7.21	40	7.68
Overall	314	7.29	104	7.69

*$F = .033$, $p = 0.856$.

Table 3 summarizes and compares the individual and total question averages for 2015 and 2017. Overall, in 2015, 91.3% of the eight post-test items were answered correctly. For the two-year follow up, 97.9% of the post-test items were answered correctly. Due to ethical requirements to protect the privacy of individual responses, it was not possible to directly compare re-test scores for given individuals in 2017. Only overall averages for each question could be compared.

Table 4 compares 2015 and 2017 post-test scores by delivery type. While all methods showed statistically significant improvements, no statistically significant differences by delivery type were noted in 2017.

Analyzed by sex (see Table 5), no statistically significant differences were measured between men and women on 2015 or 2017 post-test knowledge retention as well.

Analyzed by region/community (see Table 6), in 2015, Mepuagiua Mogeia's mean score (6.70) was significantly lower than Mepuagiua Sede's (7.59). By 2017, however, all knowledge scores were within 0.2 of each other, and no statistically significant differences were found. One participant interviewed in Tetete Sede Nova was from Tetete Mahara Central and so was excluded from this analysis.

Table 7 summarizes answers to the open-ended, free-response question, 'What was the condition of the beans when you opened the jerrycan?' by the 95 participants who used the jerrycan method at least once. Total number of responses is greater than 95 because participants sometimes provided more than one observation.

When asked to evaluate the effectiveness of the jerrycan storage method, all of the 95 farmers who used the jerrycan method at least once evaluated it positively. An open-ended question

Table 6. Comparison by region/community for 8-item post-test score for 2015 and 2017.

	2015 Post-test		2017 Re-test	
	Number	Mean score	Number	Mean score
Tetete Region	$N = 66$		$N = 43$	
Tetete Sede	27	7.4	19	7.6
Tetete Sede Nova	12	7.3	7	7.8
Tetete Napuatchi	27	7.6	17	7.8
Mepuagiua Region	$N = 115$		$N = 60$	
Mepuagiua Mogeia	37	6.7	27	7.7
Mepuagiua Hulane	39	7.0	21	7.8
Mepuagiua Invacula	39	7.4	12	7.7

Table 7. Participant responses about the efficacy of the mobile ESD jerrycan solution.

Response	# of Participant Answers
No problem/beans in good condition	45
No insect damage	42
Good for germination	15
Clean seed	10
Good for seed	5
Good for eating/cooking	5
Did not change color	1
Beans good for selling	1

Table 8. Participant perceptions of efficacy of the mobile ESD jerrycan solution.

Response	# of Participant answers
No insect damage	46
Good for germination	30
Good condition/no damage	20
Economic value of beans increased	12
Good to eat or cook	7
No need to use chemicals	5
Keeps beans dry	2
Do not have to buy seed	1
Can use this method for other crops	1
Keeps beans clean	1

Table 9. ANCOVA for any effects of demographic variables on survey responses.

Covariance	Type III sum of squares	Df	Mean square	*F* value	*p* value
Age	0.267	1	0.267	0.455	0.501
Sex	0.058	1	0.058	0.098	0.755
Interviewer	0.553	1	0.553	0.949	0.332
Harvested	0.084	1	0.084	0.143	0.706
Hectares planted	2.166	1	2.166	3.788	0.054

asked them to explain why they believed the method was effective; Table 8 summarizes their responses. Total number of responses is greater than 95 because participants sometimes provided more than one observation.

From the ANCOVA (see Table 9), while no statistical significance was detected for the factors of age ($p = .50$), sex ($p = .75$), interviewer ($p = .33$), total kilograms of beans harvested ($p = .71$) in both seasons, or total bean hectares planted in both seasons ($p = .054$), the result for 'total bean hectares planted in both season' might benefit from additional research (see Discussion below).

4. Discussion

This study follows-up on mobile ESD training from two years prior in order to assess the knowledge retention and solution adoption of an improved postharvest bean storage technique in northern Mozambique. Results show an 89.4% adoption (use) of the technique by participants more than once, with an overall knowledge retention of 97.9% for the steps needed to securely prepare and store beans using the mobile ESD jerrycan technique.

Farmers in Mepuagiua specifically tend to grow beans only in the dry season (May to October), while farmers in Tetete tend to grow beans in both the dry and the wet season (November to March). This helps to determine when farmers need seed for planting. In fact, only 2 of the 104 farmers reported selling all of their beans immediately postharvest; the remainder reported saving at least some of the beans, more often for future planting than for food.

'Beans in good condition,' 'no insect damage,' and 'good for germination' were the three most frequent participant descriptions concerning the effectiveness of the mobile ESD jerrycan method. While farmers in the area historically have had scant access to good sources of seed for future planting and are otherwise forced to buy them if they cannot store and re-use their own seed, bruchid damage to stored beans has previously made such stored seeds unusable. In the present study, all of the 95 farmers who used the jerrycan method reported using the stored beans for seed at least once. This suggests that one of the most – perhaps *the* most – important reason for adopting the jerrycan method was to preserve seed more securely for future planting.

Mocumbe (2016) previously noted that participant farmers had very little knowledge of the jerrycan storage technique before training, although a few were already using it. Training on the mobile ESD jerrycan technique was highly effective for all methods of delivery at the time; in this follow-up study, we measured an 89% adoption rate at two years. Moreover, among the 104 participants overall, 96 (or 92.3%) told an average 8.49 other farmers about the postharvest bean storage technique, while 57 (or 54.8%) demonstrated the technique to an average 6.35 others – thus enhancing the local diffusion of this innovation.

Pragmatically speaking, a high adoption rate in conjunction with the desired outcome of the innovation (in the present case, better secured storage of postharvest inventory for future seed use) represents a more immediately relevant result than high knowledge retention scores. That is, that farmers report successfully using the jerrycan method to store beans counts more toward farming sustainability and livelihood improvement for farmers regardless of whether or not the proposed steps of the technique's use have been exactly remembered or followed as trained. Nonetheless, the average knowledge retention score increased from 2015 to 2017 from 91.3% to 97.9%. Only the score for one step – 'fill the jerrycan completely with beans, shaking it to ensure there is no space to circulate air inside' – decreased slightly from 96.5% to 94.1% correct, with both scores already representing high levels of knowledge retention.

Also, although not statistically significant in this analysis, it seems plausible that the variable 'total bean hectares planted' might correlate to a greater number of correct answers on follow-up post-testing, given that farmers planting more beans might also pay more attention to the storage of beans. However, this suggestion requires further research. Similarly, that no correlation was found between the number of correct answers and participant educational level in 2015 not only agrees with recent findings by Bello-Bravo, Zakari, et al. (2018) but also suggests that the knowledge-delivery approach of mobile ESD is both appropriate and effective for learners of any educational level (whether literate, low-literate, or illiterate) (Bello-Bravo et al., 2020).

More broadly, adult learning theory argues that connecting any offered curricula to the lived realities of adult learners improves knowledge transfer (Douthwaite & Hoffecker, 2017; Illeris, 2009; Knowles, Holton, & Swanson, 2012; Mezirow, 2000; Taylor, 2017; Tennant, 2020). Mocumbe (2016) established that postharvest bean losses were an important farmer concern and that farmers were already motivated to learn about jerrycans as a locally feasible, improved postharvest bean storage solution that addressed an important problem in their lives. This pre-interest of farmers in the storage solution likely helped to ground motivation for the high (89.4%) rate of adoption (c.f., Antonio, de Assis, de Aquino, Rifan, & Pinto, 2019; Bello-Bravo, 2020). From an adult learning perspective, this high solution adoption rate results, at least in part, from how the curricular message delivered both matched a recognized critical need and also drew on locally available resources, as already recognized and voiced by the farmers as correctly meeting that need (Adusei-Asante & Adibi, 2018; Bello-Bravo et al., 2020; Thomas, 2018). This underscores why careful attention given to farmer perceptions about problems relevant to them not only can pay off but also points to why eliciting participant involvement in the process of identifying solutions they might subsequently adopt matters (Lineberry, 2019).

The notion of boundary spanning – as a cross-domain activity that enables the translation of knowledge from one (curricular) domain to another (the learner's) – also points to a key function for making these kinds of connections and relevance (Christ, Burritt, Guthrie, & Evans, 2018; Daley & Jeris, 2004; Mason, 2003). In the present study, the promise of improved storage of beans, particularly as seeds for future planting, connects directly to the lack (or difficulty) of access to seeds that a majority of farmers in this area experience. Nonetheless, just as Schmidt et al. (1997) emphasized that actually practicable solutions in an area may sometimes emerge only by engaging the specific affordances of an area, this also points to the need to (1) cooperatively level the playing field between solution providers and recipients in order to develop and implement workable solutions (Lineberry, 2019; Mason, 2003), and also (2) recognize or empower a requisite variety of flexibility in any solutions offered such that local actors can translate those solutions into locally feasible and practicable forms (Milgroom & Ribot, 2019; Ribot & Peluso, 2003).

5. Conclusions and implications

This study followed-up on knowledge retention and solution adoption two years after the delivery of mobile ESD training on a hermetically sealed jerrycan solution for improving postharvest bean storage to farmers in two rural Mozambican communities. Overall, this follow-up found high residual levels of curricular knowledge retention, particularly with respect to key innovation knowledge items (97.9%), and a very high (89%) more-than-once solution adoption of the jerrycan method that farmers had been trained in.

These results suggest that mobile (ICT-delivered) ESD training messages are at least equally as effective for knowledge transfer/retention and solution adoption as traditional, extension lecture-demonstration methods over the long term. While previous research found that 'traditional'-only knowledge delivery performed less well than mobile ESD alone or when used in conjunction mobile ESD, in the follow-up, no statistical differences were found for knowledge retention and adoption for the different delivery methods. While future research could confirm or explore any relationship between this longer-term pattern and the initial form of delivery, mobile ESD itself offers an already usable and effective method of message delivery for diverse populations regardless of sex, educational level, socioeconomic status, age, or geographic remoteness.

These results have important implications as well for how to supplement the current limited ability of extension agent resources to deliver messages to farmers, given that mobile ESD can more cost-effectively reach remote, low-/non-literate, and other underserved populations. As more and more farmers adopt or gain access to video-enabled cellphones (or smartphones) through ownership or sharing – and as data plans and/or usage costs become more competitively affordable – this ICT approach can be used very effectively as a channel for information delivery and thus a means for changing behavior and securing desired solution adoption, outcomes, and impacts. Given that both mobile ESD and traditional delivery methods led to adoption and multiple uses of the recommended jerrycan storage method, access to this channel and its comparatively lower cost of delivery can become criteria in the future for determining which method, or combination of methods, is most suitable for given projects.

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