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Facilitated discussions increase learning gains from dialectically localized animated educational videos in Niger

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ABSTRACT

This study measured the knowledge transfer and appeal of information and communication technologies (ICTs) used to deliver education for sustainable development (ESD) content to farmers in Niger experiencing major crop losses from the insect pest *Maruca vitrata*. ICT-ESD content consisted of two dialectically localized and animated videos that address food security problems of cowpea insect herbivory and the shortage of integrated pest management strategies in rural Niger. Comparing pre-test/post-test knowledge transfer for both animated videos when either (1) watched alone (AVO), or (2) in conjunction with a facilitated group discussion prior to post-testing (AVD), results from 90 farmers in 3 rural Nigerien villages showed statistically significant knowledge transfer in both AVO and AVD groups and still greater gains in the AVD group. Importantly, while a majority of participants expressed a preference for learning from such animated videos and a willingness to share their new knowledge and the videos with others, this finding did not statistically significantly associate with education level, supporting the idea that AVO/AVD is an inclusive strategy for low-literate learners within developing-nation contexts. Recommendations and theoretical implications for ICT-ESD implementations in resource-limited areas are also discussed.

KEYWORDS

Informal education; low literate learners; information and communication technology; animations; sustainable development goals

1. Introduction

Answering the United Nation's (2016) call for education for sustainable development (ESD) solutions to agricultural and food security challenges around the world effectively mandates the development and implementation of information and communication technology (ICT) approaches, as the most widely available and cost-effective means for delivering agricultural ESD, especially in Africa (Aker, 2010; Aker & Mbiti, 2010; Armstrong, Diepeveen,

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& Gandhi, 2011; Asongu & Biekpe, 2017; Mutembei, Tsuma, Muasa, Muraya, & Erastus, 2015; Odiaka, 2015; Uesugi, 2008). For any ICT-ESD solution to succeed on the continent, however, it must be rooted in the actual realities of problems faced and the local capacities for solutions there.

For food security challenges in rural Niger, for instance, while cowpea (*Vigna unguiculata*) is a main source of protein, farmers can experience crop losses of up to 80% (Singh, 1990; Singh, Singh, & Jackai, 1984). These losses are due not only to droughts and poor or degrading soil conditions but especially to inadequate access to economically, environmentally, and socially sustainable integrated pest management (IPM) strategies for controlling crop predation by *Maruca vitrata*, the cowpea pod borer (Atachi & Djihou, 1994; Kay, 1979; Khaemba, 1980). In light of these constraints, the often prohibitive cost, challenges resulting from farmer illiteracy, and increased human, ecological, and agricultural risks posed by synthetic pesticide use (Khan & Damalas, 2015; Khan, Mahmood, & Damalas, 2015; Midega et al., 2012; Parsa et al., 2014) make the use non-synthetic pest control IPM systems for solving local food security challenges around cowpea in rural Niger economically, environmentally, and socially more rational, desirable, and sustainable (Agunbiade et al., 2010; Agyekum, Donovan, & Lupi, 2016; Bello-Bravo & Pittendrigh, 2018; Pittendrigh et al., 2017; Pretty & Bharucha, 2015; United Nations, 2016).

However, adequately educating farmers to elicit their buy-in around any proposed non-synthetic IPM approach is a key factor for any successful ESD implementation. Research into farmers' perceptions and knowledge around pests and forms of pest control meant to increase crop production (Nwilene, Nwanze, & Youdeowei, 2008) has found that despite the economic, environmental, personal, and social disadvantages of synthetic pesticides (Ahouangninou et al., 2012; Ajayi, Akinnifesi, & Sileshi, 2011; Williamson, Ball, & Pretty, 2008), farmers can often perceive them as the most reliable approach for controlling pests – seeing them as either more effective than alternatives, as the only option available, or simply a last resort, even as they may fail to be adequately effective anyway (Jensen, 2000; Toda & Morishita, 2009). As our current study found, for instance, even when farmers are aware of a more cost-effective and less harmful alternative IPM pesticide, they can still remain reluctant to use it.

1.1. Deploying ICT-ESD: the Scientific Animations Without Borders approach

ICT-ESD is potentially well-positioned to cost-effectively and sustainably overcome this resistance and achieve the kind of change in values, behaviors, strategies, and lifestyles necessary for bringing about a sustainable future for all people and societies (UNESCO, 2002) – that is, for changing minds around taking up more sustainable cultural practices (United Nations, 2016).

The ICT-ESD approach developed by Scientific Animations Without Borders (SAWBO), for instance, has been used in dozens of locations to deliver linguistically localized animated video ICT-ESD on video-enabled mobile phones. These videos are aesthetically appealing (Abbott et al., 2017; Bello-Bravo, Seufferheld, et al., 2013; Maredia et al., 2017; Miresmailli, Bello-Bravo, & Pittendrigh, 2015) and elicit reports of, or have demonstrated, participant buy-in around solutions depicted (Bello-Bravo, Nwakwasi, Agunbiade, & Pittendrigh, 2013; Bello-Bravo, Seufferheld, et al., 2013; Lutomia & Bello-Bravo, 2017; Mazur et al., 2013; Mocumbe, Abbott, Mazur, Bello-Bravo, & Pittendrigh, 2016a). Moreover, they have shown greater knowledge transfer and learning gains over other knowledge transfer approaches (Bello-Bravo, 2017; Bello-Bravo, Lutomia, & Pittendrigh, 2017; Bello-Bravo, Tamò, Dannon, & Pittendrigh, 2018; Lutomia & Bello-Bravo, 2016; Maredia et al., 2017) and have proven cost-effective and deployable in resource-limited contexts (Bello-Bravo, 2017; Bello-Bravo, Lutomia, & Pittendrigh, 2017), including settings with sociocultural limitations on print literacy and access by participants (Bello-Bravo et al., 2011; Bello-Bravo, Seufferheld, Agunbiade, & Pittendrigh, 2010; Lutomia & Bello-Bravo, 2017; Miresmailli et al., 2015; Pittendrigh & Bello-Bravo, 2010). They also are potentially self-replicating as an approach (Pittendrigh et al., 2017).

Importantly, these comparatively small-sized ICT-ESD animations, deliverable and redistributable on video-enabled mobile phones and other means, are not only easily *accessible* through the ever-expanding digital infrastructures of Africa to people even in remote locations – or in countries like Mali where Internet access remains expensive – but are also feasibly *useable* by African populations who are often technologically literate in mobile phones, but not laptops, desktops, tablets, or other modern ICT devices, and who also typically face constraints from limited data plan/size usage on mobile phones. Ribot and Peluso (2003) have similarly anchored their theory of access on these two factors: being able not only to *obtain* a given resource (as access) but also to put that resource to use.

But while mobile phones arguably provide the current maximum of digital ICT access for African populations, gendered differences around access, use, and especially additional safety issues for women in general (Clouse et al., 2015; Dodson, Sterling, & Bennett, 2013; Hafkin, 2000; Overå, 2008; Sanya & Odero, 2017) alert us to the growing digital divide between men and women and the need to implement any offered solutions in equitably sustainable ways (Huyer, Hafkin, Ertl, & Dryburgh, 2005; Ihm et al., 2013; Warschauer, 2004). In light of these possible constraints on ICT-ESD knowledge transfer delivered on mobile phones, this research explores whether facilitated discussion can enhance such knowledge transfer, if not overcome these constraints.

1.2. Study purpose and theoretical framework

Previous research using the kind of SAWBO ICT-ESD animated video described above compared pre-test/post-test knowledge test scores by farmers who learned the content either (1) by viewing the video for ESD content or (2) by participating in a traditional extension teaching on the same ESD content (Bello-Bravo et al., 2018). That study measured equal or greater knowledge gains in the farmer group that watched the ICT-ESD video compared to traditionally extension-taught farmers on the same content (Bello-Bravo et al., 2018). In this study, we compared pre-test/post-test knowledge gains by farmers who watched two SAWBO ICT-ESD animated videos either (1) alone (AVO) or (2) in conjunction with an extension agent facilitated discussion prior to post-testing (AVD). In terms of content, the two ICT-ESD videos addressed: (1) knowledge and perceptions around the life cycle of the *M. vitrata* cowpea pest, and (2) knowledge and perceptions around the advantages, preparation, and use of a proposed non-synthetic IPM pest control approach (neem seed extract).

One research question of this study, then, was: *does facilitated discussion after viewing an ICT-ESD animated video generate significantly increased learning gains*? While we anticipated that ICT-ESD knowledge transfer for both AVO and AVD would yield significant learning gains, consistent with previous research, we also expected the knowledge transfer for AVD to be greater still. Intuitively self-evident as this may seem in advance, scientific parsimoniousness requires us to test this self-evidence. Such an assumption, in any case, begs the question of what and how any such greater increase might come about and, in principle, disregards any potential cases where facilitated discussion might decrease knowledge gains.

SAWBO's ICT-ESD approach is anchored both in theories of adult learning that emphasize the importance of connecting any ICT knowledge to be transferred to the interests, prior knowledge, and lived experiences of adult learners (Chaiklin, 2003; Knowles, 1984; Vygotsky, 2012) – in the present case, the farmers' expressed concerns about *M. vitrata* predation on their cowpea crops and their desire to control this pest – and also in the affective potential for content engagement and the general appeal of multimedia learning (Clark & Mayer, 2016; Mayer, 2002; Slovic, Finucane, Peters, & MacGregor, 2002); indeed, "many theorists have given affect a direct and primary role in motivating behavior" (Slovic et al., 2002, p. 398). Moreover, the perceived authenticity of animation as an aesthetic form (Bishko, 2007), as well as the perceived "pseudo-neutrality" of animated content (Kaid & Noggle, 1998), further help to support the credibility of the scientifically validated content in SAWBO videos for viewers.

In the previous research cited above, Bello-Bravo et al. (2018) observed flare-ups of interpersonal and/or power conflicts around ESD content playing out between the learners and the extension agent teacher (as an authority) that did not occur with the animated videos themselves; that is, credibility of ESD content can become an issue for extension-learning participants in a way not seen for video-learning participants. Similarly, we have observed specifically how learners using mobile phones are in their locus of control with respect to viewing and re-viewing ICT-ESD content at their own pace and leisure, even in busy and distracting environments (Bello-Bravo, Lutomia, & Pittendrigh, 2017).

These several factors underpin the theoretical premises of SAWBO ICT-ESD knowledge transfer. At the same time, however, we recognize that ICT delivery of e-learning is not a silver bullet and does not always successfully transfer knowledge (Clark & Mayer, 2016); women in Africa, for instance, have expressed a preference for face-to-face learning over computer-based instruction (Tata & McNamara, 2018). Similarly, the negative effects of computer illiteracy on perceptions of ICT interventions have long been noted (Mahmood & Medewitz, 1989).

In general, a part of the intuition that facilitated discussion might increase knowledge gains can include the idea that repetition (of the ESD content) enhances or reinforces knowledge transfer. While AVD affords a second exposure to ICT-ESD content, we cannot simply assume that this repetition must explain any greater measured knowledge transfer. For example, the evidence for time-on-task pedagogies – which generally assume that knowledge repetition and practice can automatically affect knowledge transfer – remains ambiguous and in need of more contextualization (Dekkers et al., 2017; Giroux, 2010; Kiramba, 2016). As such, if facilitated discussion does result in statistically significant increases in knowledge transfer, then this study can further ask what factors enable this in the AVD group. This may potentially disclose aspects of facilitated discussion that are productive for enhancing and/or supporting knowledge gains from digitally delivered ICT-ESD curricular content taken in isolation.

Equally, while we are committed to finding, disseminating, and facilitating real-world solutions to problems faced by people in vulnerable communities, it is not the purpose of this study to test the proposed IPM solution itself here. We offer the following descriptions of the videos partly for the sake of clarity, but more to emphasize how the scientific grounding and affective appeal of the videos inform their knowledge transfer capacity.

The two SAWBO-produced ICT-ESD animated videos used as curricular content in this study are (1) *Biocontrol of legume pod borer* (*Maruca vitrata*), which details both the life cycle and behavior of *M. vitrata* as well as how non-synthetic control agents can be used to reduce pest populations (see SAWBO, 2017a) and (2) *Natural insecticide from neem seed*, which describes how to select neem fruits, prepare them in powdered form, and then produce a liquid suitable for spraying on crops (see SAWBO, 2017b). Both videos incorporate local and global, scientifically grounded and validated work by researchers who have been testing non-synthetic IPM approaches for cowpea pest control, including neem (*Azadirachta indica*) seed extracts (Abudulai & Shepard, 2003; Das, 1987; Sokame et al., 2015; Zakari et al., 2017).

Also crucial and consistent with SAWBO practice elsewhere (Bello-Bravo, Lutomia, Abbott, et al., 2017; Bello-Bravo, Lutomia, Madela, & Pittendrigh, 2017; Bello-Bravo, Olana, & Pittendrigh, 2015), the verbal component of the videos were translated into the local Hausa dialect. While research shows that people from diverse cultural groups are generally open to learning from the same or similar sets of culturally non-specific animated images, dialectical inaccuracy of voiceovers is reported as off-putting and can diminish the effectiveness of ICT knowledge transfer (Bello-Bravo & Baoua, 2012; Bello-Bravo, Dannon, Agunbiade, Tamò, & Pittendrigh, 2013; Bello-Bravo, Dannon, et al., 2017; Bello-Bravo, Olana, Enyadne, & Pittendrigh, 2013; Bello-Bravo, Seufferheld, et al., 2013). Addressing people in their own language is not only communicatively pragmatic (Nonaka & Takeuchi, 1995) but can also mitigate any on-going, oppressive power dynamics around the use of ex-colonial or national languages in Africa (Kiramba, 2016), thus better fostering trust in any solutions communicated (Levin & Cross, 2004; Szulanski, Cappetta, & Jensen, 2004) and making them potentially more authoritative, credible, and liable for uptake (Bello-Bravo, Lutomia, Madela, et al., 2017).

2. Materials and methods

2.1. Methodology and data collection

From 6 to 7 January 2016, a total of 90 cowpea producers from 3 Nigerien villages – Bamo, SherkinHatsi, and TsamiyarKoura in the southwestern Maradi region (see Figure 1) – were identified for participation with the help of a local agriculture extension agent. The sole selection criterion was that the individual participated in cowpea crop production. A total of 30 participants per village were then randomly assigned to one of two experimental groups: (1) animated video only (AVO) or (2) animated video in conjunction with an extension agent facilitated discussion after participants had watched the video one to several times (AVD).

Researchers conducted structured interviews with each participant either in Hausa or French using a locally fluent translator. This approach accommodated and avoided embarrassment for any low- or non-literate participants. Structured interviews collected

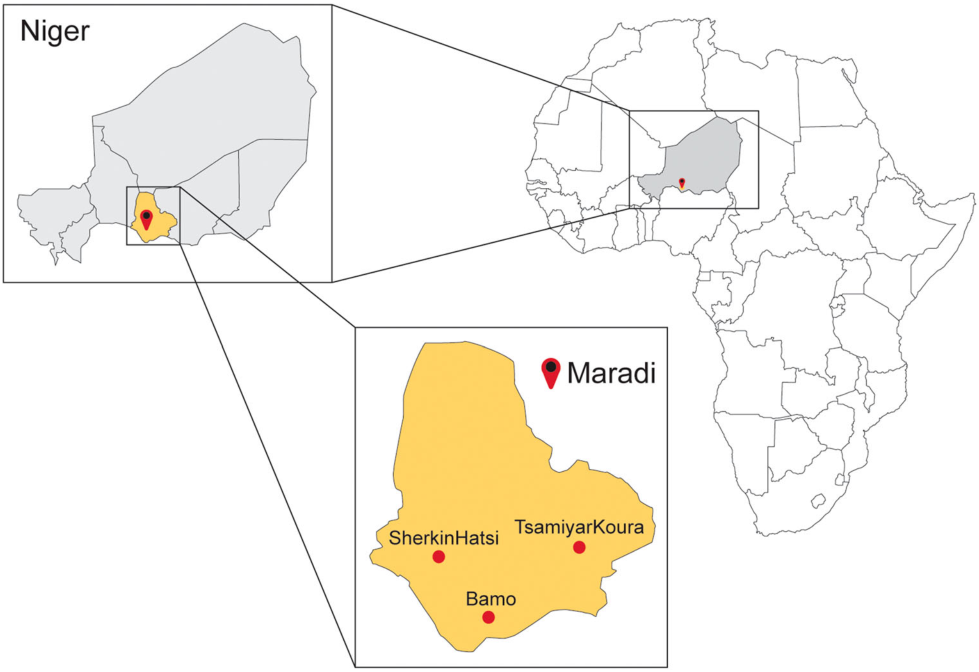

Figure 1. Study location (Bamo, SherkinHatsi, and Tsamiyar Koura villages, Maradi Region, Niger).

demographic information and administered knowledge pre-tests on the ESD content of the two curricular videos.

To deliver the ESD content, both videos were shown on a laptop operated by the research team; the videos were watched collectively by each AVO or AVD group. AVO participants were then immediately post-tested by researchers after watching the videos to measure ESD knowledge gains, while AVD participants engaged an extension agent in a facilitated discussion about the content of both videos and then were post-tested (see Figure 2). After post-testing, all participants were interviewed by researchers about their experience and provided their evaluation of learning via animated video. Across all three villages, this yielded 45 AVO and AVD participants.

2.2. Data analysis

For the Chi-square analyses, the data were analyzed using the crosstabs method of descriptive statistics method from SPSS. Analysis included (1) demographic characteristics of the participants, (2) pre-test/post-test knowledge about the animated video content of both videos, and (3) differences between the AVO and AVD groups. For the purpose of this study, the AVO group served as a control, but it is crucial to emphasize that we propose this only to supply a relative comparison with the AVD group (see Section 4).

Analysis of covariance was performed using SAS 9.4 in Windows 10. The PROC MIXED model was used after the PROC REG model established regression relationships between pre-visualization and AVO and AVD survey answers. Educational level was also used to test for a relationship with learning gains.

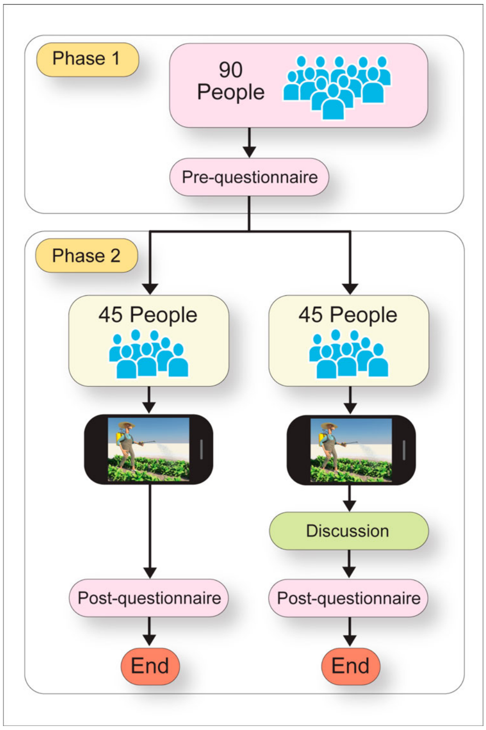

Figure 2. Survey strategy graphic map (all three villages combined).

For all aforementioned analyses, a p-value of 0.05 or less was considered statistically significant.

3. Results

3.1. Demographic characteristics

Across all three villages, participants averaged 44.6 ± 1.2 years old. While all of the participants spoke Hausa and some of them also spoke the national language, French, print literacy was generally very low, averaging only 3.4% and 9.0% of participants across the three villages for Hausa and French, respectively. Non-literacy in these languages varied from 76.4%, to 89.6%, and 98.6% in Bamo, SherkinHatsi, and TsamiyarKoura, respectively. Also, none of the participants reported having access to the Internet. None had used a computer before and were not computer literate.

Across all three villages, 68.8% of participants were women and 35.2% were men, and more than 83% reported their primary profession as farmer; all were direct stakeholders in cowpea production. Most of the participants (an average 80.2%) were members of farmers' organizations, and the majority (more than 83%) were married, either polygamously or monogamously. The overall average household size was large, generally with more than 14 people per household. The majority were also low income and had low formal education levels, with an average of only seven per household attending school (see Table 1); 50%, however, reported a Koranic education.

Table 1. Demographic characteristics.

		Village			
		Bamo	SherkinHatsi	Tsamiyar Koura	Average
Sex	Female	56.7	63.3	74.2	64.8
	Male	43.3	36.7	25.8	35.2
Marital status	Divorced	0.0	3.3	3.3	2.2
	Widow(er)	16.7	3.3	6.7	8.9
	Monogamous	43.3	20.0	40.0	34.4
	Polygamous	40.0	73.3	50.0	54.4
Number of household members	Aged 0–65	18.1	14.7	14.6	
	Aged 7–65 attending or enrolled in school	9.5	6.8	6.8	
Education	None	16.7	10.0	13.3	13.3
	Adult/alphabetization	13.3	30.0	16.7	20.0
	Koranic	46.7	50.0	53.3	50.0
	Elementary	16.7	10.0	6.7	11.1
	Middle school	6.7	0.0	10.0	5.6
Literacy by language	None	76.6	89.3	96.8	87.6
	Hausa	6.7	3.6	0.0	3.4
	French	16.7	7.1	3.2	9.0
Years lived in village	11–20 years	10.0	23.3	3.2	12.1
	Above 20 years	90.0	76.7	96.8	87.9
Principal activity	Farmer	83.3	83.3	90.3	85.7
	Other	16.7	16.7	9.7	14.3
Agricultural experience	Less than 5 years	0.0	3.3	0.0	1.1
	5–10 years	14.3	20.0	0.0	11.2
	11–20 years	3.6	16.7	0.0	6.7
	Above 20 years	82.1	60.0	100.0	80.9
Member of farmer association	No	30.0	16.7	12.9	19.8
	Yes	70.0	83.3	87.1	80.2
Duration of membership	Less than 5 years	27.3	40.0	71.4	48.0
	5–10 years	22.7	20.0	14.3	18.7
	11–15 years	18.2	20.0	7.1	14.7
	16–20 years	13.6	12.0	3.6	9.3
	Above 20 years	18.2	8.0	3.6	9.3

Importantly, while a majority of villages indicated synthetic chemical use as a primary means for crop protection, the use of neem seed extract was reported in all three. A small percentage of farmers – 6.9% and 12.0% in SherkinHatsi and TsamiyarKoura, respectively – reported using no insecticide; in the same villages, 24.1% and 24.0% respectively reported exclusively using neem (see Table 2).

3.2. Pre-test/post-test results of M. vitrata *animated video*

Table 3 summarizes the combined percentage of correct pre- and post-test answers from both the AVO and AVD groups for the *M. vitrata* biology video animation. Eleven of the 13

Table 2. Insecticide types used by percentage.

		Villages			
Question	Answers	Bamo	SherkinHatsi	Tsamiyar Koura	Significance
What is your main insecticide that you use in your crops?	Chemicals	63.3	41.4	44.0	$p = 0.18$
	Neem only	0.0	24.1	24.0	$p = 0.014$
	None	0.0	6.9	12.0	$p = 0.16$
	Chemicals and neem	36.7	27.6	20.0	$p = 0.39$

Table 3. Combination of pre-test/post-test questionnaire results from AVO and AVD groups for the *M. vitrata* biology video animation.

Question	Pre-test	Post-test	χ^2 (2df)	Significance
Do you know about *M. vitrata* damage	59.3	92.3	26.97	$p < 0.001$
M. vitrata larvae cause a lot of damage on cowpea crop	73.6	73.6	0.00	$p = 1$
The pest occurrence is found in the pod development and flowering stage	79.1	93.4	7.83	$p = 0.005$
Caterpillars attack flowers and pods	26.4	60.4	21.50	$p < 0.001$
M. vitrata larvae come from moth eggs	18.7	82.4	73.94	$p < 0.001$
The adults lay eggs on the cowpea leaves	18.7	78.0	64.16	$p < 0.001$
Eggs are pale-cream colored and flattened	19.8	75.8	57.28	$p < 0.001$
M. vitrata larvae are flattened with two rows of distinctive paired black markings on their back	24.2	80.2	55.28	$p < 0.001$
M. vitrata adults (moth) are white brown color	14.3	76.9	71.96	$p < 0.001$
M. vitrata chrysalides are dark brown	12.1	81.3	87.61	$p < 0.001$
M. vitrata pupate in the soil	13.2	80.2	82.14	$p < 0.001$
Damages are represented by flowers drop and holes on pods	20.9	69.2	42.97	$p < 0.001$
Losses caused by this pest are important	69.2	62.6	0.88	$p = 0.348$
Average	34.6	77.4	45.58	

questions showed statistically significant score improvements. In one case, the number of correct answers remained the same ($p = 1.00$); in another, the number of correct answers decreased, but this result was not statistically significant ($p = 0.348$).

For the 11 questions that improved, 6 improved from less than 20% initially correct [ranging from 12.1% to 19.8% correct] to over 75% correct [from 75.8% to 82.4%], while 3 more improved from 20.9%, 24.2%, and 26.4% to 69.2%, 80.2%, and 60.4%, respectively. The remaining two questions that improved ranged in score initially from greater than 50% to over 90% correct. On average, the number of correct answers increased from 34.6% (pre-test) to 77.4% (post-test).

3.3. AVO and AVD groups result for **M. vitrata** *animated video*

Table 4 compares the percentage of correct *post-test* answers between the AVO and AVD groups for the *M. vitrata* biology video animation. Whereas Table 3 reported the

Table 4. Comparison of post-test questionnaire results from AVO and AVD groups for the *M. vitrata* biology video animation.

Question	AVO	AVD	χ^2 (2df)	Significance
Do you know *M. vitrata* damage	84.8	100	7.42	$p = 0.006$
M. vitrata larvae cause a lot of damage on cowpea crop	58.7	88.9	10.67	$p = 0.001$
The pest occurrence is found in the pod development and flowering stage	89.1	97.8	2.76	$p = 0.097$
Caterpillars attack flowers and pods	45.7	75.6	8.50	$p = 0.004$
M. vitrata larvae come from moth eggs	69.6	95.6	10.60	$p = 0.001$
The adults lay eggs on the cowpea leaves	63.0	93.3	12.17	$p < 0.001$
Eggs are pale-cream colored and flattered	58.7	93.3	14.88	$p < 0.001$
M. vitrata larvae are flattened with two rows of distinctive paired black markings on their back	69.6	91.1	6.65	$p = 0.010$
M. vitrata adults (Moth) are white brown color	67.4	86.7	4.76	$p = 0.029$
M. vitrata chrysalides are dark brown	69.6	93.3	8.45	$p = 0.004$
M. vitrata pupate in the soil	67.4	93.3	9.64	$p = 0.002$
Damages are represented by flowers drop and holes on pods	52.2	86.7	12.70	$p < 0.001$
Losses caused by this pest are important	47.8	77.8	8.72	$p = 0.003$
Average	64.89	90.4	9.07	

combined, or average, gain in correct responses, here that average gain is disambiguated between the AVO and AVD groups. For 12 of the 13 questions, the percentage of correct responses in the AVD group showed a statistically significant increase, with an average increase overall for all 13 questions from less than two-thirds correct (64.9%) in the AVO group to over 90% (90.3%) in the AVD group. The one statistically nonsignificant increase – on the question "The pest occurrence is found in the pod development and flowering stage" – not only had the highest pre-test and post-test scores [79.1% and 93.4%, respectively] overall but also the highest and second-highest post-test scores for AVO and AVD groups alike [89.1% and 97.8%, respectively].

The statistically significant increases on Table 4 include the two questions that did *not* show a statistically significant improvement in the combined data (from Table 3). That is, the questions "*M. vitrata* larvae cause a lot of damage on cowpea crop" and "Losses caused by this pest are important" increased from 58.7% and 47.8% in AVO group to 88.9% and 77.8% in AVD groups, respectively.

3.4. Participant evaluation of M. vitrata *video animation*

Table 5 summarizes participant evaluations of the learning experience using the *M. vitrata* video animation. Questions here explicitly involve self-report and opinion, i.e. answers about how participants best learn, as well as whether they feel motivated to tell other people about *M. vitrata* as an important cowpea pest and whether they would recommend this video animation to other people as the best learning tool. Responses were tabulated using a 5-point Likert scale, 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree.

Participants in AVO and AVD groups alike preferred learning by watching an animated video [43.9% and 52.4, respectively] compared to having material presented by teachers or an agricultural specialist [9.8% and 9.5%, respectively]. Participants also overwhelmingly agreed, with more than 95% of all participants strongly agreeing, that they felt motivated to tell other people about *M. vitrata* as an important cowpea pest and would recommend

Table 5. Participant evaluation of the *M. vitrata* biology video animation.

Question	Answer	AVO	AVD	χ^2 (2df)	Significance
I learn better when I am … (Choose all that applies to you)	Taught by the teacher/ agricultural specialist	9.8	9.5	0.1	$p = 0.97$
	Watching a video/movie	43.9	52.4	0.59	$p = 0.44$
	Reading text material	4.9	0.0	2.09	$p = 0.14$
	Any two of the above methods	39.0	33.3	0.29	$p = 0.58$
	All three methods	2.4	4.8	0.32	$p = 0.57$
I feel motivated to tell other people about *M. vitrata* as an important cowpea pest.	Strongly disagree	0.0	0.0	0.0	p = n.a.
	Disagree	0.0	2.4	0.96	$p = 0.32$
	Neutral	0.0	0.0	0.0	p = n.a.
	Agree	2.5	0.0	1.06	$p = 0.3$
	Strongly agree	97.5	97.6	0.1	$p = 0.97$
I will recommend this video animation to other people as the best learning tool.	Strongly disagree	0.0	0.0	0.0	p = n.a.
	Disagree	0.0	0.0	0.0	p = n.a.
	Neutral	0.0	0.0	0.0	p = n.a.
	Agree	4.9	2.4	0.37	$p = 0.54$
	Strongly agree	95.1	97.6	0.37	$p = 0.54$

this video animation to other people as the best learning tool. Only one person in the AVD group stated feeling unmotivated to tell others about *M. vitrata* as an important cowpea pest.

3.5. Pre-test/post-test results of neem use animated video

Table 6 summarizes the combined percentage of correct pre-test and post-test answers from both AVO and AVD groups for the neem extract use video animation. For 10 of the 11 questions, score increases were statistically significant. The score increase for one question, "Do you know how to prepare the neem insecticide," was not statistically significant ($p = 0.11$) [from 71.4% initially to 81.3%], possibly because participants were already familiar with neem use as a cultural practice in the area.

Unlike the *M. vitrata* biology video, there was better preexisting (pre-test) knowledge/perception around neem extract use by participants, ranging, with one exception, from 40.7% to 74.7% correct answers initially. One question "Neem extract can be used for various purposes" had only 12.4% correct responses initially. This question also had the lowest number of post-test correct responses (46.2%). Leaving this one question aside, the average number of pre-test/post-test correct answers was 57.1% and 85.0%, respectively; when this question is included, the averages were 53.0% and 81.5%, respectively. Both of these pre-test scores [53.0% and 57.1% alike] are higher than the pre-test scores for *M. vitrata* biology [34.6%].

3.6. AVO and AVD groups result for neem use animated video

Table 7 compares the percentage of correct *post-test* answers between AVO and AVD groups for the neem extract use video animation. Here again, while Table 6 reported the combined, or average, gain in correct responses, here that average gain is disambiguated between AVO and AVD groups. While the percentage of correct answers to all questions in the AVD group were higher than in the AVO group, the improvement was statistically significant ($p = 0.048$) for only one question, "The neem extract has to be immersed for 24 hours before it can be used."

Notably, for the AVO group, the average post-test score for neem seed use was higher [79.8%] than the post-test scores for *M. vitrata* biology [64.9%], again likely due to

Table 6. Combination of pre-test/post-test questionnaire results from AVO and AVD groups for the neem seed use video animation.

Question	Pre-test	Post-test	χ^2 (2 df)	Significance
Neem extract can be used for various purposes	12.1	46.2	25.58	$p < 0.001$
Do you know how to prepare the neem insecticide?	71.4	81.3	2.46	$p = 0.11$
When making neem insecticide the preferable color of seeds is brown	40.7	79.1	28.02	$p < 0.001$
You would pound the neem seeds into fine powder	60.4	84.6	13.35	$p < 0.001$
The neem extract has to be immersed for 24 hours before it can be used	51.6	89.0	30.44	$p < 0.001$
Neem insecticide is highly recommended for spraying	46.2	86.8	33.76	$p < 0.001$
When spraying with neem, spray only the green part of the crop	58.2	90.1	24.12	$p < 0.001$
I would share information about using an insecticide like neem	51.6	86.8	26.41	$p < 0.001$
Neem insecticide is much less expensive than chemicals	60.4	86.8	16.30	$p < 0.001$
Have you or someone you know ever used neem?	56.0	74.7	7.01	$p = 0.008$
Is neem extract effective?	74.7	91.2	8.74	$p = 0.003$
Average	53.0	81.5	19.65	

Table 7. Comparison of post-test questionnaire results from the AVO and AVD groups for the neem seed use video animation.

Question	AVO	AVD	χ^2 (2 df)	Significance
Neem extract can be used for various purposes	32.6	60.0	6.86	$p = 0.009$
Do you know how to prepare the neem insecticide?	73.9	88.9	3.35	$p = 0.067$
When making neem insecticide the preferable color of seeds is brown	71.7	86.7	3.06	$p = 0.08$
You would pound the neem seeds into fine powder	78.3	91.1	2.88	$p = 0.08$
The neem extract has to be immersed for 24 hours before it can be used	82.6	95.6	3.89	$p = 0.048$
Neem insecticide is highly recommended for spraying	82.6	91.1	1.43	$p = 0.23$
When spraying with neem, spray only the green part of the crop	84.8	95.6	2.96	$p = 0.085$
I would share information about using an insecticide like neem	82.6	91.1	1.43	$p = 0.23$
Neem insecticide is much less expensive than chemicals	82.6	91.1	1.43	$p = 0.23$
Have you or someone you know ever used neem?	71.7	77.8	0.43	$p = 0.50$
Is neem extract effective?	87.0	95.6	2.09	$p = 0.14$
Average	79.8	90.5	2.71	

preexisting knowledge/perceptions around neem use in the area. For both topics in the AVD group, by contrast, the average percentage of correct responses was roughly comparable, i.e. 90.5% for neem extract use and 90.3% for *M. vitrata* biology.

3.7. Participant evaluation of neem use animated video

Table 8 summarizes participant evaluations from both groups for the learning experience using the neem extract use video animation. Similarly to the participants' experiences of learning with the *M. vitrata* video animation, participants in AVO and AVD groups alike preferred learning by video animation over having material presented by teachers or an agricultural specialist.

3.8. Analysis of covariance

While an analysis of covariance on all survey answers for both animated videos in the AVO and AVD groups was performed in order to determine a relationship, if any, between

Table 8. Participant evaluation of the neem seed use video.

Question	Answer	AVO	AVD	χ^2 (2 df)	Significance
I learn better when I am … (Choose all that applies to you)	Taught by the teacher/ agricultural specialist	9.8	9.1	0.1	$p = 0.91$
	Watching a video/movie	46.3	52.3	0.29	$p = 0.58$
	Reading text material	7.3	0.0	0.033	$p = 0.068$
	Any two of the above methods	34.1	31.8	0.052	$p = 0.81$
	All three methods	2.4	6.8	0.9	$p = 0.34$
I feel motivated to tell other people about neem as a natural insecticide.	Strongly disagree	0.0	0.0	0.0	$p =$ n.a.
	Disagree	0.0	0.0	0.0	$p =$ n.a.
	Neutral	0.0	0.0	0.0	$p =$ n.a.
	Agree	4.8	6.8	0.16	$p = 0.68$
	Strongly agree	95.2	93.2	0.16	$p = 0.68$
I will recommend this video animation to other people as the best learning tool.	Strongly disagree	0.0	0.0	0.0	$p =$ n.a.
	Disagree	0.0	0.0	0.0	$p =$ n.a.
	Neutral	0.0	0.0	0.0	$p =$ n.a.
	Agree	7.1	6.8	0.03	$p = 0.95$
	Strongly agree	92.9	93.2	0.03	$p = 0.95$

educational level and survey answer, we found no significant relationship for any item (all p-values were greater than 0.05 for all cases). Additionally, demographic variables – such as gender and primary occupation – similarly showed no statistically significant results ($p > 0.05$).

For the *M. vitrata* animation, we found a significant positive relationship on two questions regarding what people knew about the pest biology and their desire to tell others about *M. vitrata* as an important cowpea pest ($p < 0.05$ for both comparisons). Similarly, for the neem animation, participants who had previously prepared neem extract expressed a greater level of motivation to tell others about neem as a non-synthetic insecticide ($p < 0.05$ for both AVO and AVD groups). Participants who were motivated to share information about neem also showed a greater desire to the share the neem animation itself ($p < 0.05$ for both AVO and AVD).

4. Discussion

Results of this study suggest that cowpea farmers are eager to learn about ESD content [i.e. about pests responsible for crop losses and additional IPM approaches to combat them], that learning gains occurred significantly for the AVO and AVD group, and that still greater learning gains were measured for AVD on ICT-delivered ESD. That participants reported much higher preferences for video animation learning over other forms of learning rationalizes their use as a complementary, if not primary, educational strategy for extension services, particularly in resource-limited and difficult-to-access areas. Similarly, more than 90% of participants reported that they would recommend video animations as a form of teaching for others and stated that they felt motivated to share the information in both videos with others.

While this demonstrates that dialectically localized ICT-delivered ESD video animations are both feasible and effective for sustainable education efforts, the more comfortable participants were, or became, with respect to a given ESD concept (e.g., knowing more about pest biology or having experience with preparing neem solution) made them more likely to consider sharing their knowledge and/or the animated videos with others. These quantitative outcomes are in keeping with the qualitative interactions reported with participants at the end of the study sessions.

Most importantly, however, educational levels were *not* a factor (i.e. were not statistically significant) with respect to these statements, which suggests that AVO and AVD approaches both are appropriate for audiences of diverse literacy levels. This is a very important finding for information technology use in areas with reduced or no access to education in general – where print literacy or literacy in African national or administrative languages is limited or non-existent – but especially for socioeconomic sectors with significant female populations, given that women and girls often have less access to education even when it is available in an area. In this study, for instance, participants were more than two-thirds women.

In this research, the focus involved whether facilitated discussion (AVD) could enhance AVO knowledge transfer. Accordingly, we deployed ICT-ESD delivery using a laptop operated by the research team in order to control for any computer literacy barriers in participants but at the cost of not attempting to leverage the affordances of individually operated mobile phone ICT-ESD delivery for knowledge transfer to participants. The merits of this laptop and group-presentation approach include convenience for the ICT-ESD delivery team in terms of logistics, travel, and organization, as well as fewer technological resource demands (i.e. requiring only one laptop, rather than a number of loanable mobile phones for all participants); for participants, however, this approach introduces potential issues around access (if they are otherwise unable to attend or travel to the presentation) as well as any social factors that arise from group dynamics in public learning settings.

By delivering ICT-ESD on a laptop to groups, we sought to control variables as much as possible so as to investigate AVD learning gains over AVO. The demonstration of this notwithstanding, we acknowledge that any ICT-ESD delivery mode must be mindful of the barriers to access that a given approach can raise for participants – specifically, in this case, any prohibitive costs in time or transportation that would preclude attending a learning session, and the possibility that some potential participants in an area may never hear about the opportunity until after the fact, if at all. There may also be settings where limitations on electricity, space, or other infrastructural elements may make even a simple presentation on a laptop to a group difficult.

The results also show that while we measured learning gains from animated video (AVO) alone, these gains were further increased by facilitated discussion (AVD) on the contents for both ESD videos, albeit to varying degrees and not always statistically significantly so. In the following discussion, while we explore how AVD supplemented AVO learning gains, we must first acknowledge the more basic point that, in any effort to achieve a widest possible impact from any ESD intervention, ICT benefits from non-ICT supplementation.

In the *M. vitrata* biology video, for instance, all but one question showed a statistically significant increase in the percentage of correct responses in AVD group. The one question that did *not* show a statistically significant increase was "The pest occurrence is found on pod development and flowering stage" [from 89.1% pre-visualization to 97.8% post-visualization]. Given the high pre-test scores, this finding may indicate considerable prior knowledge among participants with respect to how and when to recognize *M. vitrata* on crops. In other words, prior knowledge entailed that there was little locally that needed to be learned here.

However, also for the *M. vitrata* video, while the 6 of 13 question scores on *M. vitrata* biology that were <20% correct on the pre-test all increased to >86% correct on AVD post-tests, the one question with comparatively higher pre-test knowledge (26.2%) "Caterpillars attack flowers and pods" showed the lowest post-test scores for AVO and AVD taken together (60.4%) and AVD (75.6%). While these are still statistically significant increases, it may be that translation of terminology (into Hausa) for "caterpillar" and "pod" could have affected test comprehension. Nonetheless, while comprising the only <80% correct question item for AVD, the outcome is still statistically significantly improved over AVO alone.

Conversely, only one question showed a statistically significant increase in the AVD group for neem use. Given that participants from all three villages reported some familiarity with neem use, and that in two villages more than one-fifth of the farmers reported exclusively using neem (see Table 2), the relatively higher pre-test knowledge scores on this topic compared to *M. vitrata* biology would seem to reflect this prior knowledge. Despite this, it was the question, "Neem extract can be used for various purposes" that had the overall *lowest* pre-test score for the combined AVO and AVD groups [12.1%

pre-test compared to 46.2% post-test, $p < 0.001$]. Given the local familiarity with neem use and that 73.9% and 88.3% in the AVO and AVD groups alike answered *yes* to the question, "Do you know how to prepare the neem insecticide," this suggests that any pre-test or post-test *no* to "Neem extract can be used for various purposes" could reflect either (1) a local prior knowledge that only perceives neem as useful for a *single* purpose (as a non-synthetic pesticide) rather than *various* purposes or (2) a lack of prior knowledge that neem could be used for various purposes at all. If 73.9% and 88.3% of participants in the AVO and AVD groups alike are already familiar with preparing neem as a non-synthetic pesticide, then the increased post-test awareness of neem's affordance as a non-synthetic pesticide may have occurred only amongst those who were not previously aware of this fact.

Importantly, comparing only post-test results on the question "Neem extract can be used for various purposes" (Table 7), AVO and AVD yielded 30.6% and 60.0% *yes*, indicating a statistically significant ($p = 0.009$) improvement in AVD. We detect an important contribution to information technology learning in this result besides the self-evident improvement of learning gains that resulted from facilitated discussion. Arguably, for any ESD intervention – in this case, to promote a more economically, environmentally, and socially sustainable IPM alternative over current synthetic pesticides – to impart the idea that the intervention is *usable* must be a central goal, and yet this basic idea (notwithstanding the learning gains measured for it and the still greater ones in the AVD groups) was not 100% clear to participants at the end of the testing or discussion. Why?

From the above analysis, we can detect a possible ambiguity in the question "Neem extract can be used for various purposes" in the word "various." For those unfamiliar with neem use, neem may have "no" use, much less various. While for those who are familiar with neem use, neem may have "one" use, not various. Moreover, for those who perceived "no" use initially and answered *no* on the pre-test, on the post-test, knowledge transfer could have prompted them to answer *yes* instead. However, for those who initially perceived neem as having "one" use and answered *no* to "various" on the pre-test, their answer might still be *no* on the post-test as well.

Importantly, the curricular content of this question does not turn on the *number* of uses that neem might have (none, one, or various), but simply seeks to elicit an acknowledgment that it *can* be used as a non-synthetic pesticide. In the AVO group, this ambiguity of question interpretation remains unaddressed before the post-test, whereas a facilitated discussion, even without explicitly stating that neem has "various" uses during that discussion, could make clear the intended knowledge emphasis of the test question and thus result in a correct *yes* answer during post-testing.

To suggest this is not a critique of the question or even a proposal that changing the wording will necessarily yield greater learning gains. One cannot ignore as well that translation (in this case into Hausa) created an additional layer of possible linguistic ambiguity in even the most exactly worded (English) question. Rather, this points to an inherent challenge for digitally delivered ICT educational content, as subject to learner variations of interpretation and/or invisible premises or assumptions in the wording of a curricular content, that can be overcome – even casually or accidentally – by a facilitated discussion. It should be noted that the AVD facilitated discussions did not consist of a review of each question individually with a provision of the expected correct answer. As such, the discussions never set out to explicitly insist that neem has "various" uses but simply stressed the usability of neem as an alternative pesticide in a way that the results show contributed to a statistically significant increase of correct answers for this question even as worded.

We would stress again: no ICT content will ever be perfectly interpretable by all users nor can ICT content developers anticipate every possible reading and misreading of content. That this marks a limit on what ICT affords must be taken as a feature not a bug. Equally so, while facilitated discussions are manifestly more responsive to individual learners' confusions, questions, readings, and misreadings of curricular content, they too can never perfectly answer (much less anticipate) every misreading, all the more so when translation is involved. In the present case, then, we could not identify any explicit moment in the discussions when an initial *no* answer might have transformed into a *yes*. As an artefact explicitly rooted in the interactions of the specific learners at that specific time and specific place (perhaps, even, only as listeners and not speakers in those discussions), and consistent with the view that sometimes learning and solutions can *only* arise through such concrete interactions (Bakhtin, 1981; Schmidt, Stiefel, & Hürlimann, 1997), we can still emphasize that AVD generally yielded greater knowledge transfer and learning gains.

Also curiously, from the *M. vitrata* video, the number of *yes* answers to the question, "The larvae cause a lot of damage on cowpea crop" remained unchanged (Table 3). Answers of *yes* for this item had the second-highest pre-test score (73.1%), and it is interesting to speculate whether the high levels of pre-test *yes* answers could reflect prior knowledge from the ongoing biocontrol agent release programs that have been in existence in Niger, in collaboration with farm groups, for over a decade. However, the lack of post-test score increase suggests that participants initially answering *no* were not persuaded to change their mind by the video. Nonetheless, the number and persistence of *no* answers sheds light on ICT-ESD as well.

Given that 59.3% of participants on the pre-test expressed knowing of *M. vitrata* damage and 79.1% recognized that pest occurrence is found during the pod development and flowering stages, this may suggest not so much a shortage of knowledge about the effects of this insect pest but more a reduced sense of severity or alarm about the pest's presence. Specifically, the question asks whether "the larvae cause *a lot of* damage on cowpea crop" (emphasis added). Perceptions about what constitutes "a lot of damage," especially given differential experiences by farmers with regard to this pest, may explain the results. That is, those participants who had previously experienced crop losses as "a lot of damage" due to *M. vitrata* retained their *yes* answers on the pre-test and post-test, while those who did not perceive "a lot of damage" from *M. vitrata* retained their *no* answers pre- and post-test.

Like the previous example, the curricular emphasis of this question is not the numerical volume or extent of *M. vitrata* damage (as "a lot of damage") but an urgency around the destructive capacity of the pest in general; as such, facilitated discussion may have made the question's intended emphasis clearer and yielded greater knowledge transfer in the AVD groups. However, another factor may be involved here instead or in addition. It may be that the prior experiences of some individual farmers with *M. vitrata* simply may not elicit the emphasized sense of urgency if they have been fortunate enough to avoid insect predation in general or if their crop protection means have proven adequate. Even so, for those farmers who did *not* initially have this sense of urgency about *M. vitrata* damage, to witness a discussion where fellow farmers expressed such urgency could potentially have motivated a switch from a *no* to a *yes* answer on this question.

Our point is not, of course, that witnessing this must always, or can only, achieve such an end; rather, we are simply offering a possible mechanism to explain the statistically significantly higher knowledge transfer measured in the AVD group for this question. In general, digitally delivered information technology curriculum tends typically to be experienced alone, without a social context of other learners. While this can often be entirely suitable for certain kinds of instrumental or skills-based knowledge, for knowledge transfer that more widely involves others in a community – e.g. public health policies, educational efforts to address social inequities, or addressing the community-wide effects of *M. vitrata* predation even if you yourself are doing well – the social setting of a facilitated discussion may better support the desired knowledge transfer; that is, in this case, the elicitation of a sense of urgency around *M. vitrata* damage where it did not previously exist or did not exist to a degree adequate for prompting behavioral change towards it. Previously in other research, we witnessed an instance where two participants spontaneously began acting out the experiment's proposed ICT-ESD intervention for the other participants, resulting in a collective call-and-response teaching session involving everyone (Mocumbe et al., 2016a). This kind of collective reinforcement, correction, and learning not only transformed learners into teachers, it was a social learning situation that effectively supplemented isolated ICT learning as well.

Similarly, comparing pre-test and post-test answers to the question, "Losses caused by this pest are important" (Table 7), the number of *yes* answers *decreased*. Although statistically not significant, it seems unlikely that a video designed to raise concern about crop losses from *M. vitrata* would decrease that concern. We would suggest that the ESD video itself may have empowered participants with a sense of having a better means for identifying the pest and addressing its effects. It is not that losses caused by this pest are now less threatening ("important") but that the threat of that problem no longer seems as threatening ("important") as previously because it is now, in principle, more manageable.

As with the previous example, statistically significantly higher knowledge transfer for this question was measured in the AVD groups compared to AVO. That is, if participants felt more empowered in the AVO groups about their options for dealing with an "important" threat to their livelihoods, then facilitated discussion enhanced this shift still more. Whereas the example just prior to this one may have elicited a sense of urgency in participants where there had been less or none previously, here the social setting of AVD may allow community members to see that they are not alone with their options for taking action to reduce this pest threat and that they have a (potential) community of allies in that effort.

It is possible as well, in all of the AVD settings, that a desire to publicly display a correct knowledge of the tests played a role as well. As a practical matter, in the effort to effectively transfer knowledge around ICT-ESD interventions, whether the measured knowledge transfer occurred due to a "genuine" desire to learn the content and/or as a result of some public reputation factor in participants could be a matter for future research; at a minimum, greater knowledge transfer occurred with AVD compared to AVO.

5. Recommendations and conclusion

While video animations alone (AVO) increased participant learning, facilitated discussion post-viewing (AVD) further enhanced those gains. This resonates with other findings that human interaction serves to enhance computer instruction (Bello-Bravo, Lutomia, Abbott, et al., 2017; Mocumbe, Abbott, Mazur, Bello-Bravo, & Pittendrigh, 2016b; Tata & McNamara, 2018). Tata and McNamara's (2018) observation that women statistically significantly preferred face-to-face instruction over computer-based instruction may link to our findings here as well, given that the majority of participants were women and that higher learning gains were found in social (face-to-face) interactions.

However, the well-established appeal of animated videos as a preferable means of instruction over more traditional extension teaching methods (Bello-Bravo, Dannon, et al., 2017) does not yet guarantee buy-in to any ICT-ESD content-solutions offered. Our findings suggest that "delivering the content" through ICT has greater effectiveness for changing minds toward more economically, socially, or environmentally sustainable solutions (United Nations, 2016) when supplemented by facilitated discussion. Part of this enhancement involves an irreducible feature of ICT-only instruction – its vulnerability to learner interpretation and unrecognized assumptions or premises in the curricular content – that facilitated discussion can fill in or overcome, whether accidentally or without being aware of the conditions needed for correcting those interpretations or assumptions.

In general, the aspirational goal of any ESD effort should be 100% coverage, even while acknowledging that no ESD delivery can be total or perfect. The stakes are too high, too many species (humans and otherwise) are at risk, too many cultures and lives are under threat (United Nations, 2016) to be satisfied with C+ results. Moreover, in women-dominated economic sectors, their reduced access to education – and thus lower print and technological literacy, as well as generally poorer socioeconomic circumstances – mandates smart-approaches able to reach this vulnerable but critical population. As such, while ICT-ESD in African contexts is essential due to the several ways that it can reach otherwise inaccessible areas in the most cost-effective manner, "lo-tech" approaches (e.g. dialectically localized ICT-ESD delivered on video-enabled mobile phones) can have much greater reach, appeal, and efficacy.

Tata and McNamara (2018) observed how training for a desktop-based farm productivity software package could not proceed without having first to train participants on how to hold and use a mouse, how to "click the desktop" and interface with the operating system, and, in some cases, even turn on the computer and monitor; that is, the training assumed a computer literacy in the participants not common in that area. ICT-ESD interventions that make "lo-tech" (e.g. mobile phone-based) assumptions about technological literacy in African contexts, in contrast, will less frequently encounter this barrier and be able, when encountering it, to more quickly close that gap with simple training (on how to operate a video application on a video-enabled mobile phone). Facilitated discussion also can overcome these barriers, where technological literacy can be assumed among presenters or in technologically literate participants who can share devices or phones with others who are not.

In other research in Ghana, we have observed how social participation can play a role in ICT-ESD knowledge transfer (Bello-Bravo, Lutomia, & Pittendrigh, 2017). For women in a

Ghanaian market, they were loaned mobile phones and viewed ICT-ESD videos at their leisure while they worked in their stalls, interrupted by friends or childcare needs, sometimes drawing an interested crowd of others to view the video as well. From this and the evidence in this study for enhanced knowledge transfer in AVD groups, future research could investigate whether the inclusion of a "social or group component" to enhance ICT learning, in general, represents a needed theoretical addition to ICT approaches.

Pragmatically, such a "group" component can potentially also extend the reach of ICT-ESD. In places where phone ownership, resources for digital access, Internet speed, and even infrastructures for education are constrained, a SAWBO ICT-ESD video can be accessed, shown, and then subsequently shared from a single phone to a group of people. Ideally, such access offers a theoretically self-replicating (viral) element to ICT-ESD as well, since viewers can share video content via Bluetooth® or other means to other viewers. This also functions to transform learners into teachers without risking the curricular authority of the video's scientifically validated content. As such, the viral reach of such ICT-ESD is limited only by mobile phone infrastructures and linguistic borders across which ICT-ESD's dialectical localization becomes verbally obsolete.

For ICT-ESD in general, this research underscores the importance of being contextually mindful of ICT accessibility; while computer literacy cannot be assumed as a prerequisite for effective ICT-ESD implementation – in "first world" settings as well – even assuming mobile phone literacy can inadvertently exclude populations in need of the ICT-ESD. As such, future research on dialectically localized ICT-ESD delivered on mobile phones remains required to determine how to extend the reach of this approach as much as possible to *all* people, including the blind or deaf, those in areas still without mobile phone infrastructures, or across the gendered usage and safety divide for women.

Moreover, while evidence from this research supports recommending that facilitated discussion could be added to ICT-ESD interventions in order to enhance their knowledge transfer effectiveness, further research is needed explore the wider range, variety, and scale of any such "social or group component" supplement. For instance, is paired learning or some larger group more or less effective than facilitated discussion in general? Or are there forms of local group interaction that ICT-ESD implementers can draw on as alternatives to facilitated discussion; the case of spontaneous and theatrical student teaching noted above may be exemplary in this respect (Mocumbe et al., 2016a). Moreover, are there aspects of facilitated discussion (or other group/social interaction) that decrease knowledge transfer?

Additionally, with respect to the theoretical underpinnings of ICT knowledge transfer in general, these results raise the question whether there might be two broad classes of ICT intervention: those that necessarily require a social or group component for optimal knowledge transfer and those that do not. Further research, as well as meta-analyses of previous research, could help to disclose "social" factors involved in "individualized" ICT learning successes, any missing "social" elements in sub-optimal "individualized" ICT learning outcomes, and "individual" factors that were either conducive or non-conducive to ICT learning outcomes in "social" or "group" learning settings. In the present research, for instance, while AVD post-test knowledge scores ranged from 86.7% to 100%, the "gaps" that remain raise the question whether any group dynamics in the facilitated discussions prevented or inhibited some individuals from asking clarifying questions that might have increased post-test knowledge scores to 100% on all questions.

By proposing these lines of research, we are not advocating for perfect results as the only acceptable outcome. It is, rather, that the urgency of these needed interventions demands we set a high bar as a goal. Ultimately, Nigerien opinion, amongst the population studied, may remain mixed about neem use and the problem of *M. vitrata*. But not everyone needs to be convinced after the videos that crop losses due to herbivory by this pest necessarily require a *new* intervention or that *only* neem seed extract offers a feasible alternative. Ultimately, the idea that there are *alternatives* to present methods (and potentially better ones) is the most important one for spurring beneficial behavioral change with respect to *M. vitrata* in the area, whether by new (more sustainable) methods or by better-deployed old ones. That knowledge transfer around this central idea was in all instances more facilitated by AVD is a key finding for this kind of social change.

While future research could follow up to determine what factors did, or could have, supported the desired behavior change in the area – and what technical support could have been offered by those bringing the ICT-ESD in the first place or by their humanitarian sponsors – it is not generally a claim or assumption of teaching that it must (or does) guarantee behavioral change as well. For the kinds of situations of urgency addressed in this research, however, we therefore would also recommend some variety of institutional follow-up structure to accompany interventions – even if only a grassroots one – to support and implement the desired ICT-ESD solution. This is needed because, as Ribot and Peluso (2003) imply in their theory of access, knowledge itself is not power; rather, knowledge and the means to put it to use is.

Disclosure statement

No potential conflict of interest was reported by the authors.

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