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Using mobile technology to increase safety awareness among dairy workers in the United States

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ABSTRACT

Background: Modern U.S. dairy farm operations present multiple safety hazards which may result in worker injuries, illnesses and fatalities. The U.S. industry trend towards large-herd milking operations, especially in the Western U.S., necessitates an increased number of workers on each farm. The U.S. dairy workforce is comprised of an increasing percentage of immigrant workers with limited English proficiency which presents a safety training challenge. Our objective was to develop, deliver and evaluate safety awareness training to U.S. dairy farm workers using mobile tablets as a personal learning environment.

Methods: A non-random sample of 1,436 dairy workers received safety awareness training on a mobile device platform. Kirkpatrick Levels 1, 2 and 3 training effectiveness evaluations were performed.

Results: Approximately 58.7% of training participants received a middle school education, and 22.7% were from Guatemala who reported K'iche' as their native language. A statistically significant large effect size suggests safety knowledge was gained among training participants when comparing post-test scores to pre-test scores (Level-2). Training participants rated their training experience favorably (Level-1), and applied knowledge gained in their daily work activities three months after training (Level-3).

Conclusion: Our findings suggest the utilization of mobile learning techniques is an effective means to deliver safety awareness training content to dairy workers. Dairy worker safety training should be culturally, linguistically, and literacy appropriate and comprehensive in nature to include all applicable dairy safety hazards. Our observations support the use of mobile devices as just one component of a more comprehensive health and safety management program on farms.

KEYWORDS

dairy; safety; training; mobile learning; m-learning

Introduction

The United States (U.S.) Agriculture, Forestry, and Fishing (AgFF) ranks among the most dangerous industrial sectors with an incidence rate of 5.7 nonfatal occupational injuries per 100 full-time workers and a rate of 23.2 fatal work injuries per 100,000 full-time workers.¹ Included in this industrial sector are dairy farm operations which present multiple safety hazards. There were 5,500 recordable nonfatal injuries on dairy farms with more than 11 employees in 2016, equating to an incidence rate of 5.6 injuries for every 100 workers. This rate is nearly double the national private industry nonfatal industry rate. In 2016 alone,

there were 46 worker fatalities reported on U.S. dairy farms.¹

The national industry trend toward large-herd milking operations, especially on western dairy farms, necessitates an increased number of workers on each farm to perform a multitude of tasks including milking, feeding, cow and calf care, and maintenance activities.^{2–4} Similar to other U.S. agricultural businesses, dairy farms employ a large percentage of immigrant workers.⁴ Immigrant agricultural workers in the U.S. are mostly from Latin America, including Mexico, Central and South America.^{5,6} The agricultural workforce is composed mostly of Hispanic males

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with limited English-proficiency.⁷ Many immigrant agriculture workers speak little or no English with the common language being Spanish on dairy farms which presents a safety training challenge.^{2,6,8}

Worker safety training is just one component of a comprehensive safety management program which also includes management leadership, worker participation, hazard identification and control, and program evaluation.⁹ Effective worker safety training is one mechanism to facilitate the reduction of safety incidents.¹⁰ Safety training is necessary to inform workers of hazards and equip them with the knowledge and resources to protect themselves and coworkers.¹¹ Methods of safety and health training can include synchronous classroom-based lectures, asynchronous computer-based training, or learner-centered, individualized methods which can include hands-on demonstration.¹⁰ Limited prior studies have addressed safety training effectiveness in the agricultural sector. A lecture-based grain storage safety training was developed and evaluated among students enrolled in secondary agricultural education programs.¹² Kim et al.¹³ explored the effectiveness of participatory training for promoting health and safety and reducing agricultural work-related injuries among Korean farmers. Lee et al.¹⁴ reported on the training effectiveness of a comprehensive training certification program in California. Anger et al.¹⁵ demonstrated orchard workers with limited formal education can learn job safety from computer-based instruction and translate the knowledge to work practice changes.

Despite large-herd dairy farms employing increasing numbers of workers, 97% of dairy farms in the U.S. are still family owned and operated.¹⁶ Our on-farm observations of dairy operations in multiple states have revealed dairy operations typically lack many resources to provide effective safety training. Dairy farms often do not have human resource or training departments, or a dedicated safety officer who is trained in safety hazards and regulatory compliance. Other safety training challenges include limited or non-existent facility space to conduct group trainings, limited computer resources or internet/cellular connectivity, and high employee turnover which requires continuous onboarding training for new employees. Geographical remoteness of dairy

farms often limits the expedient identification and availability of safety trainers. Because dairy production is dependent on consistent and timely milking and feeding routines, any disruption of operations could have profound effects on cow health or production, making it difficult to pull workers off the job for training. Most dairy owners or managers rely on “on-the-job-learning,” which instructs workers on “what to do” and “how to do it” according to the needs of the facility. Despite the importance and benefits of on-the-job-learning, this approach often lacks the comprehension aspect of why a particular task should be performed in a certain way. The challenge of delivering quality and effective training in the dairy sector which accommodates multiple learning styles, cultural differences, and multiple languages has never been larger than it is today given changing workforce demographics.

The delivery of training content has progressed tremendously in the past decade, transitioning from traditional classroom instruction, to the utilization of desktop computers and the internet (e.g., electronic or e-learning) to present day mobile learning or m-learning. M-learning refers to the use of mobile or wireless devices for the purpose of learning.¹⁷ Smartphones, handheld and tablet PCs, laptops, and personal media players can all fall within this scope. An analysis of prior studies regarding mobile learning revealed m-learning has most frequently been used in teaching and learning environments for higher education and elementary-school students, and only five studies have evaluated training effectiveness which all included higher education students.¹⁸ Although m-learning is in its infancy in terms of both technologies and pedagogies, it has the potential to dramatically improve the dissemination of safety training content to workers in remote locations such as dairy farms. Utilizing novel m-learning approaches has the potential to overcome many of the safety training challenges inherent on dairy farm operations.

In a review prepared for the 2010 Agricultural Safety and Health Council of America/National Institute for Occupational Safety and Health conference, Arcury et al.¹¹ recommended that the health and safety community should “provide health and safety training to agricultural workers in a variety of formats (visual, hearing, hands-on)

so that communication of concepts and practical information fits the learning styles that are most effective for individual workers.” In response to this recommendation, our objective of this m-learning project was to develop, deliver, and evaluate safety awareness training to U.S. dairy farm workers using mobile tablets as a personal learning environment. For this safety training project, we (1) developed methodology to deliver safety training using a mobile device in resource-limited settings (i.e., remote dairy farms); and (2) examined the effectiveness of the training. Further, we sought to identify and report challenges and solutions when creating, delivering, and evaluating safety training using mobile devices.

Methods

Training content development

In 2010, there was a collaborative effort between multiple institutions to ensure dairy farm workers and managers had the most accurate and up-to-date information available on the basic principles for farm worker health and safety. New Mexico State University’s (NMSU) Dairy Extension collaborated with dairy owners and workers, as well as the U.S. Dairy Education Training Consortium (formerly Southern Great Plains Dairy Consortium), USDA National Institute of Food and Agriculture, the Southwest Center for Agricultural Health, Injury Prevention, and Education and the High Plains and Intermountain Center for Agricultural Health and Safety (HICAHS). These collaborations resulted in a series of short educational vignettes that were compiled and made available for distribution on two DVDs in both English and Spanish. The target training audience included new dairy farm employees who needed general training on safety issues across the dairy farm, as well as training for specific farm jobs or positions.¹⁹ After production and distribution of over approximately 6,000 DVDs in both the U.S. and internationally, training vignettes were deployed on the mobile platform using Apple iPad™ tablets with the intent of enhancing the efficient and effective delivery and sustainability of safety training content to dairy workers on remote dairy farms.

Training participant sample

A convenience sample of 1,432 dairy workers was recruited from 40 farms in the states of New Mexico ($n = 451$), Texas ($n = 511$), Colorado ($n = 179$), Kansas ($n = 131$), and New York ($n = 160$) between March of 2015 and August of 2016. All but one of the farms where trainings took place were private, family-owned dairy operations. Each training session was limited to no more than 20 workers due to tablet availability. When conducting the training, we asked workers to provide details about their age, race, gender, country of origin, native speaking language, years of experience of working on a dairy farm, and job position.

This training project was granted exempt status by the University of Texas Health Science Center at Houston, Committee for the Protection of Human Subjects.

Training and data collection

Each training session was approximately 1.5 h in total duration. Training vignettes were delivered using the Articulate Storyline offline-mode application which negated the need for internet connectivity. The safety training content included two vignettes. The first vignette covered general dairy farm safety. The second vignette covered job-specific safety training that covered (1) general and outside worker safety, (2) milker and calf caretaker safety, or (3) feeder safety. After completing the first vignette on general dairy safety, workers had the option of viewing one of the three job-specific training vignettes according to their current job position. Training topics and durations are presented in [Table 1](#). Training was provided in numerous locations on farms including milking barns, break rooms, maintenance areas, conference rooms, cow treatment barns, and outside on a lawn or under a shade tent ([Figure 1](#)). Prior to training delivery, bilingual instructors provided a verbal introduction which included training purpose, learning objectives, as well as tablet navigation instruction. Each participant was provided a set of ear buds which minimized distractions while viewing training vignettes in a group setting. Some training sessions included K’iche’-speaking workers from Guatemala. This

Table 1. Safety training topics.

Vignette I: General Dairy Farm Safety (21:10 min)	Vignette II: Job-specific Training
ATV safety	<i>General & Outside worker safety</i> (17:53 min)
Cattle flight zone	Hygiene & PPE
Chemical safety	Fire prevention
Eye and ear protection	Electrical safety
Milking barn safety	Machine room safety
Moving cattle safely	Lock out/Tag out
Proper cattle immobilization	Ladder safety
PTO safety	Safety in pens
Safety around bulls	Outdoor safety & livestock-handling
Electrical safety	Lifting safety
Ergonomics	Treating cows
Livestock-handling and treatment chutes	Bull safety
Safety around heavy equipment	Ergonomics
Safety around the silage pile	Treating non ambulatory cows
Safety in the machine room	<i>Milker & Calf Caretaker safety</i> (5:04 min)
Understanding how cattle see	Cleanliness, hygiene & PPE
Waste lagoon safety	Crowd-gate safety
Working with self-locking stanchions	Milking routine safety
	Safety with chemicals
	Calf Caretaker safety
	Ergonomics
	<i>Feeder safety</i> (6:59 min)
	General feeder safety recommendations
	Drug & alcohol policy
	Safety belts
	Loader buckets
	Speed
	Awareness of workers and/or children
	Machinery Power Takeoff (PTO) safety
	Safety around the silage pile
	Silage avalanche protection
	Rollover protection (ROPS)
	Face management & uncovering

**Figure 1.** Training atmosphere on different farms.

dynamic required the bilingual coworkers to provide translation and individualized assistance from a trainer during training sessions. After training, each participant received an individualized certificate of

training completion with their name printed on the certificate. Additionally, each dairy owner received a report of the safety training with training content and a participant list.

We utilized the Kirkpatrick Four-Level Training Evaluation Model to evaluate training effectiveness.²⁰ Immediately preceding the delivery of training vignettes, each participant completed a Level-2 pretest, and immediately following each training a Level-2 posttest was completed. Each pre- and posttest included fifteen questions, which was administered using the Qualtrics Mobile Survey Software® application. Both pre- and posttests were composed of “True” or “False” and multiple choice questions addressing training content as presented in Table 1. Using Bloom’s Taxonomy of Learning, participants were asked to remember, understand, and apply safety concepts presented in the training.²¹ The following presents two questions presented in pre- or posttests:

Question 1.

Which of the following should be used when milking?

- Apron
- Gloves
- Rubber boots
- All of the above

Question 2.

True or False: When not in use, chemicals should be kept in a special room that is locked.

Pre- and posttest quizzes were administered on the same mobile device that training vignettes were presented. Quiz questions were simplistic in nature utilizing actual dairy farm work environment images with the intent of evaluating the learner’s ability to recognize safety hazards while minimizing the influence of a worker’s possible

unfamiliarity with answering quiz questions on a mobile device. Bilingual training staff were present in all training sessions to provide assistance to workers and monitor quiz taking. Scores were collected as percentages of items correct. Following the administration of the Level-2 posttest, each participant was asked to complete a five-question Level-1 evaluation concerning their learning experience with the safety training. This relatively quick approach used “happy sheets” (green smiley face = “yes,” yellow neutral face = “maybe,” and red frowning face = “no”). Three months later, instructors returned to nine randomly selected dairy farms and administered a Level-3 evaluation to training participants to assess training effect on worker safety behavior. This evaluation involved a research team member administering a five-item, self-report questionnaire which was recorded on a mobile tablet using Qualtrics Mobile Survey Software®. This approach used a conventional “yes” and “no” answer choice bank to collect information. Figure 2 depicts training and evaluation chronological activities.

Statistical analysis

For this study, statistical analysis included descriptive statistics of subject demographic characteristics, test score results and training effectiveness evaluations. ANOVA and paired t-tests were used to assess knowledge improvement from pre- to post-training. Hedges’ g estimate was used to compute effect size based on a comparison of pre- and posttest mean scores relative to pooled variances.²²

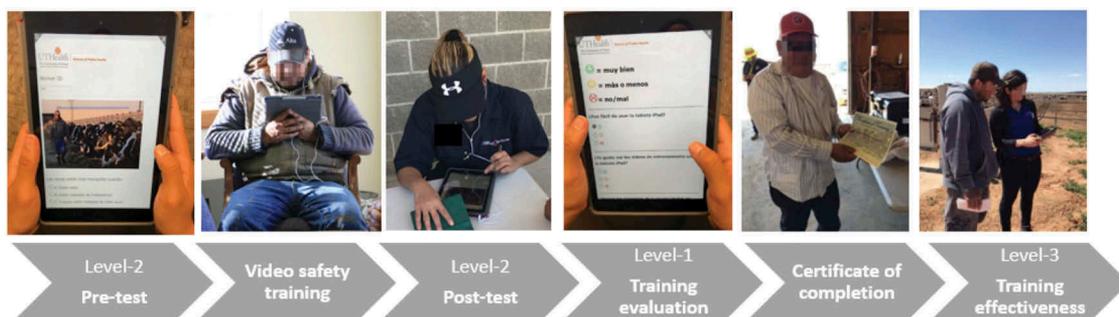


Figure 2. Chronology of safety training. Training delivery, Levels 1 and 2 evaluations, and Certificate of Training Completion were conducted on same day. Level 3 evaluation was conducted 3–6 months post-training.

All statistical analyses were performed using Stata v.14 [Stata Corp LP, College Station, TX].

Results

Mean age of workers was 34.4 (12.0) with a range of 18–79 years and 88.6% of participants were male. In total, 52% of participants reported Mexico as their country of origin, followed by 22.7% being from Guatemala, and 18.4% from the United States. Over 60% of participants reported Spanish as their native language followed by K'iche' (22.4%) and English (12.9%) (Table 2). The average years of experience working on a dairy farm was 7.4 years (SD = 9.1). A small percentage (6.1%) expressed having no formal education, 28.2% reported having elementary-school education, 24.4% reported having received middle-school education, 28.6% reported having high-school education, and 12.7% reported having received higher than a high-school education. Participating workers identified their primary job position as either milker (34.5%), feeder (4.7%), or general worker (60.8%).

Table 3 presents the results of the different evaluation levels delivered during and after training. A total of 1,432 completed Level-1 and Level-2 evaluations. Level-1 evaluation, which assessed learner

experiences with training, revealed that 90.3% of workers reported ease of use of iPad devices, 95.2% liked viewing training vignettes on an iPad device, and 94.6% liked the training atmosphere. Among all participants, 83.9% reported test questions were easy to understand, and 89.3% reported as having learned new ideas and techniques. Level-2 evaluation measured the extent to which training participants improved their knowledge of safety hazards on the dairy farm. The mean score on the pretest given before training was 74.2% (SD = 18.3) and the mean score on the same test given immediately after the training was 92.5% (SD = 9.6). A paired *t*-test revealed that knowledge improved significantly from pre- to post-training ($t(1,431) = 44.4, P < 0.05$). We observed a very large difference between mean pre- and posttest scores relative to the pooled standard deviation, resulting in an effect size estimate of 1.25 indicative of a very large learning effect.²² Statistically significant ($P < 0.05$) differences between and within pre- and posttest scores across all education levels, country of origin, and native language.

A Level-3 evaluation administered to a subsample ($n = 88$) of training participants revealed 95.4% reported as having applied safety techniques learned from the safety training, and 97.7% reported as having taking steps to prevent safety incidents involving themselves or their coworkers. Among those who observed safety hazards since receiving the safety training, 90.0% disclosed as reporting hazards to coworkers or their supervisor. Last, 100.0% of training participants reported performing their job in a safer manner since receiving the safety training. Time and budgetary constraints precluded evaluating the veracity of the assertions reported by workers or performing more a formalized safety behavior observational assessment. However, workers, owners, and managers provided anecdotal information of the benefits and effectiveness of the training exercise. Examples include the following quotes from two separate dairy farm owners:

I just want to commend you on the fantastic video and coordination of training to get all of our employees the certification. It is a wonderful program and was well received by everyone. The improvement on test scores really shows they were paying attention and that they learned from the

Table 2. Training participant demographics ($n = 1,432$).

Characteristics	Mean (SD) or Frequency (%)
Gender (%)	
Male	1,253 (88.6)
Female	162 (11.5)
Age	34.4 (12.0)
Job position (%)	
Milker	489 (34.6)
Feeder	67 (4.7)
General	859 (60.7)
Years of dairy working experience	7.4 (9.1)
Highest education level achieved (%)	
No Education	83 (6.1)
Elementary School	385 (28.2)
Middle School	334 (24.5)
High School	391 (28.7)
Higher Education	171 (12.5)
Country of Origin (%)	
Mexico	716 (52.5)
Guatemala	310 (22.7)
United States	251 (18.4)
Latin America ¹	85 (6.2)
Other ²	2 (0.2)
Native language (%)	
Spanish	892 (64.6)
K'iche'	310 (22.5)
English	178 (12.9)

¹Colombia, Cuba, El Salvador, Honduras, Nicaragua, Perú, Puerto Rico

²Netherlands

Table 3. Levels 1, 2, and 3 training effectiveness evaluations.

	Yes (%)	Maybe (%)	No (%)
Level 1 (n = 1,432)			
Q1. Was it easy to use the iPad?	90.3	7.5	2.2
Q2. Did you like watching the training videos on the iPad?	95.2	4.1	0.7
Q3. Were the test questions easy to understand?	83.9	15.5	0.6
Q4. How did you like the atmosphere of the training?	94.6	4.9	0.4
Q5. Did you learn new ideas and techniques (something new)?	89.3	9.3	1.4
		Pretest (SD)	Posttest (SD)
Level 2 (n = 1,432)			
All participants*		74.2 (18.3)	92.4 (9.6)
Language*			
Spanish		74.2 (17.5)	92.8 (8.7)
K'iche'		65.5 (17.1)	88.6 (11.5)
English		90.5 (11.4)	98.1 (5.0)
Highest education level achieved*			
No education		64.0 (18.6)	89.1 (9.9)
Elementary school		65.6 (18.4)	89.9 (11.5)
Middle school		72.1 (15.8)	92.0 (9.0)
High school		81.9 (14.4)	94.4 (7.8)
Higher education		87.5 (13.4)	96.9 (5.3)
Country of origin*			
Mexico		73.6 (17.0)	92.5 (8.7)
Guatemala		65.5 (17.1)	88.6 (11.5)
United States		88.8 (12.8)	97.6 (5.1)
Latin America		72.8 (18.9)	92.7 (10.5)
Other		90.0 (4.7)	96.7 (4.7)
		Yes (%)	No (%)
Level 3 (n = 88)			
Q1. Did you take the Dairy Safety Training using this iPad tablet?		98.9	1.1
Q2. Have you applied safety techniques that you learned from the safety training?		95.4	4.6
Q3. Have you taken steps to prevent any injuries or accidents involving yourself or coworkers because of this safety training?		97.7	2.3
Q4. Have you observed any safety issues at work?		34.5	65.5
Q5. Have you reported any safety issues to your coworkers or supervisor? (if answered "yes" to Q4.)		90.0	10.0
Q6. As compared to before the safety training, do you think you have performed your job in a safer manner?		100.0	0.0

*Statistically significant ($p < 0.05$) differences between and within pre- and posttest scores across all education levels, country of origin, and native language.

video. It takes a heck of an effort to train that many people in a 24 hr environment. Thanks for working with the shift schedules and the two locations. We plan to keep up the training with all new employees.

The feedback I got from workers was very positive. They really like the format and the ease of using the iPad to do the training. The feedback I got from the management team is that it is a good tool for new hire training and refresher training.

Discussion

Training participants and learning needs

Among those in our sample, approximately 58.7% of participants received a middle-school education. The 12.7% of participants who reported receiving a higher education level

included veterinarians, owners, or general managers. Our findings support prior studies and reviews which highlight a low education level among both dairy and U.S. agricultural workers in general.^{2,6,11} Additionally, our anecdotal observations support prior studies which recognized many dairy workers do not have a prior farming background or experience working with large animals.^{2,23} As Arcury et al.¹¹ reported, limited education among agricultural workers may affect safety training in several ways including (1) limited literacy, (2) limited development of learning skills, and (3) limited ability to learn complex concepts. As a result, the mode of delivery of safety training information to dairy workers should take this into consideration.

A survey of U.S. dairy farms demonstrated approximately 62% of the nation's milk supply was produced on dairy farms with immigrant labor⁴, and prior studies and reviews have reported the U.S. dairy workforce comprises Hispanic immigrant workers who speak little or no English.^{6,8,11,24,25} A majority of participants in our 2-year training sample originated from Mexico and Central America. More importantly, 64.5% identified their native language as Spanish and a surprisingly 22.4% identified the Guatemalan dialect of K'iche' as their native language. This observation is in accordance with Farquhar et al.²⁶ who reported the primary native language for one-quarter or more of "Latino" agricultural workers is an indigenous or Native American language which is often not written.¹¹ Farquhar and colleagues²⁶ demonstrated the learning difficulty among indigenous agricultural workers when safety training is provided in Spanish. Despite training being provided in Spanish, K'iche'-speaking participants demonstrated the greatest improvement ($P < .05$) from pretest to posttest scores.

Safety training using m-learning techniques

In an effort to maximize job task relevancy and specificity, as well as learner engagement among training participants, vignettes were offered to training participants who identified themselves as a milker, feeder, or general worker. The majority of training participants identified themselves as a general worker whose job position required work outside of the milking parlor or feeding operations. General worker responsibilities included hospital work, maternity care, calf feeding, maintenance activities, managerial duties, etc. This finding suggests any dairy safety training program should include a comprehensive overview of safety hazards that might be encountered on the dairy farm, not only in specific work environments such as a milking parlor.

A goal of safety training using mobile devices in a group setting was to provide an individualized learning experience for each worker. Each participant was provided a set of ear buds which minimized noisy distractions while viewing training vignettes. In addition, each worker was instructed

how to independently navigate each training vignette which enabled repeated viewing of a particular topic if needed. After trainer demonstration of launching and navigating training vignettes on each tablet, we observed workers having minimal difficulty navigating through each vignette, and workers sometimes viewed a specific topic vignette a second time during their training session.

Our training observations also included workers coming into the group sessions at different times due to job demands. An unexpected benefit of using a mobile platform was the ability to start individual trainings at different times thus preventing participants from missing training content if they arrived late to a session. Another benefit of using mobile devices is the lack of dependency on internet connectivity. Training sessions were provided in many farm locations including milking barns, break rooms, maintenance areas, conference rooms, or on a lawn without the need to have internet or cellular connectivity.

Our observations which included a statistically significant large effect size suggest safety knowledge was gained among training participants when comparing posttest scores to pretest scores. More specific content item analysis revealed participants had difficulty with simple animal handling concepts such as where a worker should position him-/herself in relation to the cow to facilitate the cow to move in a particular direction. Future trainings should place an increased emphasis on safety during animal-handling activities. Level-1 training effectiveness analysis suggests participants rated the m-learning training experience favorably. Additionally, Level-3 analysis three months post training suggests workers were applying knowledge gained from the training in their daily work activities as well as reporting safety hazards when identified.

At present, the U.S. dairy industry is experiencing significant labor challenges as a result of many factors which include national immigration regulatory policy and variable regional wages and benefits. As a result, many farms are confronted with high employee turnover which complicates the onboarding safety training process as new workers are hired daily. As a result of high employee turnover, safety training often must be repeated several times.¹¹ Our training observations and limited statistical assessment of

training effectiveness suggest the delivery of safety training content using mobile devices may provide one solution for the need of an efficient, expedient and reproducible delivery of safety training content to workers in the U.S. dairy industry.

We envision multiple situations or scenarios where safety training content can be delivered on dairy farms using mobile technologies. Farms of all sizes and ownership structures can utilize mobile technologies as part of a comprehensive safety training program. Farm management can purchase a single tablet to deliver safety training vignettes to individual workers, or multiple tablets to deliver training content in group sessions. Training sessions could be followed by discussion among workers or live demonstration and application of safety concepts by workers. Training can take place anywhere on a farm and does not require a formal meeting room. Mobile technologies also enable the delivery of training content at any time which enables training during night work shifts.

Training and study limitations

A limitation of delivering safety training in video-only format is that the likelihood of learning and adoption into behavior is possibly reduced. According to Edgar Dale's 'Cone of Experience' learners generally retain only 50% of what is seen and heard, but this percentage is increased to 90% if training information is verbalized and performed by the learner.^{27,28} Our safety awareness training did not provide learners an opportunity to practice in-class activities. We recommend video-based learning to be augmented with other training activities such as group discussions or worker practice of safety concepts when applicable. A second limitation was the unavailability of training vignettes in the K'iche' language. This made the delivery of training content to Guatemalan participants more challenging which limited training delivery efficiency for these specific participants. We also recognize that using dairy co-workers as interpreters/translators and non-K'iche' speaking trainers could have introduced bias resulting in an over- or underestimation of pre- and posttest

scores. A third limitation was the dependency on two different software applications. Training vignettes were deployed on the mobile platform using Articulate Storyline and Levels 1 and 2 quiz questions were administered using Qualtrics Mobile Survey Software®. Yet functional, the integration of two different software applications disrupted the flow of training by the need for training personnel to manually transition between two different software applications which took less than 10 s to complete. No data were collected to ascertain if this short interruption in training diminished the learning experience for each participant. Additionally, audio files were unable to be applied to quiz questions to assist participants who struggled with reading comprehension. This necessitated instructor assistance in completing quiz questions. The development of a mobile platform which integrates training content delivery and learning evaluation while negating the need for the learner to read text would be beneficial. A fourth limitation of our training exercise is that it did not constitute a comprehensive safety training program and should not be viewed as a comprehensive safety management program.

As previously stated, our objective was to develop, deliver, and evaluate a novel approach to the delivery of safety awareness training content to U.S. dairy farm workers using mobile tablets as personal learning environments. Our observations support the use of mobile devices as just one component of a more comprehensive safety training program on farms, and should not be viewed as a replacement of other traditional training methodologies such as live lectures, on-the-job training, coaching/mentoring, or group discussion. Any dairy worker safety training methodology should be culturally, linguistically, and literacy appropriate and comprehensive in nature to include all applicable safety hazards.¹¹ The importance of culture applies equally to the design of user interfaces for m-learning training applications. One challenge associated with m-learning is the lack of guidelines for the consideration of local culture in the design of user interfaces of m-learning applications.²⁹

In our literature search we found no prior studies investigating cultural appropriateness of m-learning among agricultural workers, or the

Latino working population in general. However, asynchronous training utilizing electronic-learning (e-learning) or mobile-learning (m-learning) devices has been shown to be positively associated with the learning effectiveness of safety education training.³⁰ Another study demonstrated that 81% of Hispanic migrant farm workers had mobile devices and were capable of sending and receiving health-related information.³¹ In light of recent reports estimating that 77.0% of adult Hispanics now own a smartphone³² and could potentially benefit from m-learning, future research should address the cultural appropriateness of m-learning safety training materials.

Study limitations included recall bias of demographic information. Some workers struggled with defining their highest level of education achieved as well as years of experience working on dairy farms/around cattle. In addition, the frequency of reported U.S. nationality may have been overestimated. Given the immigration status of dairy workers, some trainees were hesitant and cautious when disclosing their nationality; therefore, some workers could have purposely and incorrectly reported their nationality as being from the United States. As previously stated, Levels 1 and 2 quiz questions did not have a voice-over audio (in English or Spanish). While workers were assisted in completing quiz questions when needed, the possibility exists that some workers did not express the need for assistance for various reasons. As a result, pre- and posttest averages may have underestimated the base safety knowledge among participants. Last, Level 3 evaluation did not include safety behavior observation and relied strictly on self-report by workers who participated in the training which introduces a reporting bias. Albeit challenging, future Level 3 safety training effectiveness should include observational safety performance assessments, or Level 4 evaluations to include actual reported injuries over time (i.e., lagging indicators) or injury prevention activity metrics (i.e., leading indicators) which might include worker identification or correction of safety hazards or worker participation in safety-related activities such as safety meetings or committees. Only one prior study investigated relationships between dairy worker safety and injury outcomes which revealed no statistical

relationship.² Level 5 training effectiveness evaluation should also be included in future studies which would provide data related to the economic costs and benefits of this and other safety training methodologies.

Future plans and conclusions

As part of our ongoing development of training resources for the dairy industry and need to integrate opportunity for learner practice during training sessions, worker safety during animal handling training vignettes has been added to the m-learning platform. Training vignettes produced and made publicly available by the NIOSH-funded Upper Midwest Agricultural Safety and Health Center (UMASH) and the National Milk Producer Federation will be augmented with live demonstration and opportunity for learner practice in actual cow pens on farm training sites. The training objective will be to educate dairy workers on how to protect the health and safety of both themselves and cows during animal-handling activities. Additional safety training vignettes covering specific dairy farm tasks will be produced covering topics such as feeding, hospital care, maternity care, and calf care.

As Arcury et al.¹¹ reported, scant evidence exists of industry-led development and implementation of language- and literacy-appropriate health and safety training for agriculture workers. As a result of this reality and in response to a growing percentage of Guatemalan K'iche'-speaking workforce in the U.S. dairy industry, the Idaho Dairymen's Association has funded the translation of safety awareness training vignettes into the K'iche' language. However, translating training materials does not ensure that they are linguistically, culturally, and educationally appropriate¹¹; and, translated materials often need substantial evaluation and improvement to make them appropriate for a specific learning population.³³ Future plans include the continued content and training effectiveness evaluation of training vignettes delivered in the K'iche' language.

Dairy farm work has inherent safety hazards which increase the risk for injuries and fatalities among workers. Dairy farms in the U.S. primarily employ immigrant, non-English speaking workers

that present a multitude of health and safety training challenges. Our findings suggest the utilization of m-learning techniques can be one mechanism to deliver safety awareness training content to dairy workers in remote and challenging work environments. Safety awareness training using m-learning techniques can be used as one of many resource tools of a comprehensive safety management and training program on dairy farms. Further development and evaluation of m-learning safety training as part of a comprehensive safety training program is needed to ensure the cultural, linguistic, and literacy needs are met among this vulnerable working group.

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Notes on contributor

All authors attest that they have made substantial contributions to this manuscript including (1) the conception of the design of the study, (2) data acquisition, analysis and interpretation of work, (3) drafting the manuscript including revision for intellectual content, and (4), approving the submitted version of the manuscript. Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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