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Research Article

Revolutionizing agricultural residue burning behavior with virtual training: Exploring the Transtheoretical Model

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ABSTRACT- Most of the research conducted on the Transtheoretical Model (TTM) of Change has focused on health and psychological issues, with limited application in the context of agricultural and environmental behavior change. However, in this innovative study, the effectiveness of interventionist virtual education in changing the behavior of burning crop residues was examined using the behavior change theory. The research employed an experimental design and a quasi-experimental pre-test/post-test design with a control group. The statistical population consisted of 400 wheat farmers, and a sample of 120 participants was selected using purposive sampling. Data were collected through a researcher-made questionnaire and analyzed using SPSS software. The questionnaire comprised four constructs: self-efficacy, the process of change, decisional balance, and stages of behavior change. The findings of this study demonstrate that virtual education based on the TTM can pave the way for effectively managing agricultural residues by enhancing self-efficacy, decision balance, and stages of behavior change. Moreover, the results highlight the broader applicability of the TTM beyond the domains of health and psychological pathology. It can be effectively utilized to address environmental behaviors, such as agricultural residue management. Consequently, it is recommended that researchers and planners incorporate the TTM in behavior change programs, transform the traditional perspective on agricultural education, and leverage virtual education as a complementary approach to formal education.

INTRODUCTION

Over the past decade, conservation agriculture has experienced consistent growth globally, with an annual increase of over 10 million hectares. By 2018/2019, the area devoted to CA reached 205.4 million hectares, representing 14.7% of the world's total cropland. This notable adoption has been particularly evident in Asia, Africa, and Europe, driven by improved organization and collaboration among farmers (Kassam et al., 2022).

In Iran, conservation agriculture was first implemented in 2007, covering 150 hectares across four provinces. Although it gradually spread to other regions, by 2014, only 955,000 hectares of agricultural land were practicing conservation agriculture (Zallaghi, 2014). This figure was relatively low compared to developed countries, where only 5% of farms adopted this approach between 2007 and 2014. Given the significant challenges faced by the agricultural sector, the development of conservation agriculture was deemed essential (Latifi et al., 2016). By 2023, however, the area under conservation agriculture had increased to 3 million hectares (Conservation Agriculture Network in Iran, 2023), indicating substantial growth in the adoption of sustainable agricultural practices nationwide.

In the province of Kermanshah, conservation agriculture initiatives began with the introduction of direct seed drills and soil tillage machines in 2009. Over time, the province saw a considerable rise in the availability of conservation agricultural machinery and equipment, as well as various promotional activities aimed at raising awareness about conservation agriculture (Ahmadi et al., 2020). Ravansar, a city within Kermanshah province, stands out as a significant agricultural hub, especially in crop cultivation, ranking third in agricultural production after Kermanshah and Islamabad-e-Gharb. Given its potential for double cropping, effective management of crop residues is essential for optimizing the cultivation of second crops (Kermanshah Agricultural Profile, 2016).

This research aims to examine the impact of virtual educational methods on crop residue management among wheat farmers in Ravansar County, utilizing the meta-theory of change model. This study holds significance for several reasons. Firstly, the meta-theory of change provides a comprehensive framework for behavioral change among wheat farmers, despite its limited use in agricultural behavior change research. Secondly, while formal education has been the main focus in most studies,

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the recent COVID-19 crisis has highlighted the effectiveness of alternative educational methods, such as virtual training. Distance learning and e-learning have proven to be valuable in sustainable education, with research acknowledging their effectiveness in enhancing knowledge and awareness (Harizan et al., 2015; Robelia et al., 2011). Agricultural companies and institutions in the United States and Australia have already incorporated e-learning as a crucial part of their educational programs and strategic management (Leary & Zane, 2006).

Considering the importance of sustainable agricultural practices and the potential of virtual education, this research aims to explore how virtual educational methods can impact crop residue management among wheat farmers in Ravansar County, ultimately contributing to the understanding and promotion of conservation agriculture in the region.

Importance of crop residues

Crop residues, such as stems and roots, serve as valuable sources of essential soil nutrients, including carbon (C), nitrogen (N), phosphorus (P), and potassium (K) uptake (Zhang et al., 2008). Burning these residues can have irreparable consequences for agricultural soil, leading to the loss of 80% of nitrogen, 25% of phosphorus, 21% of potassium, 60% of sulfur, and other organic soil materials (Singh et al., 2018). According to studies, if improper management practices of agricultural residues, such as burning straw and stubble, continue, it disrupts natural ecosystems (Hesammi et al., 2014; Sarkar et al, 2020; Myint et al, 2021) and subsequently gives rise to a plethora of issues and challenges, including increased greenhouse gas emissions (Sun et al., 2016; Zhao et al, 2020) and intensified climate changes (Victor et al., 2015). This, in turn, results in reduced soil health, plant organic matter, productivity, nutrient availability, and local microbial populations (Zhao et al., 2017; Krishna & Mkondiwa, 2023).

Currently, intelligent management of agricultural residues (as an innovative approach) can transform these seemingly burdensome residues into wealth (Kumar et al., 2017). This management approach, by returning plant residues to the soil, enhances soil structure and reduces bulk density, thereby increasing water storage capacity, water use efficiency, and soil aeration. With its continued implementation, it leads to increased organic matter, nutrient replenishment in the soil, and ultimately soil fertility (Venkatramanan et al, 2021; Liu, 2020; Chen et al., 2019). In other words, this type of management can mitigate global warming (due to reduced farm fires) and promote carbon sequestration, resulting in increased cereal yields and ultimately food security (Zhang et al., 2008).

Review of behavioral models on agricultural crop residue burning

Behavioral models are the best criteria for predicting factors that can influence behavior change, serving as a guide identifying important factors. Moreover, these models are useful for predicting behavior change or designing successful interventions. In the following, attempts have been made to compare commonly used behavioral models in terms of 7 important behavioral constructs (Table 1).
Based on the investigations conducted among behavioral models, the TTM, Multi-Theory Model (MTM), and Social Cognitive Theory (SCT) have shown greater comprehensiveness compared to other behavioral models. To select the most comprehensive and appropriate research model, an analysis of the strengths and weaknesses of the top three models was carried out. The investigations revealed that each of the three identified top models possesses its specific strengths and weaknesses. Considering the objective of the current research, which was to promote behavior change and observe its effects on the target audience, the TTM was chosen as the foundational model for the study (Table 2).

Introduction to the components of TTM

The TTM offers a comprehensive framework for understanding and facilitating behavioral change by delineating the stages of change and identifying suitable interventions for achieving sustainable transformations. Its essential components encompass the stages of change, processes of change, decisional balance, and self-efficacy, which collectively aid in developing effective strategies for behavior modification (Vaida, 2023). Additional explanations and details regarding these components will be provided in the following sections.

Change stages

Individuals require different interventions at each stage, and this classification enables us to apply appropriate interventions based on the stages (Yalçınkaya-Alkar & Karanci, 2007).

There are five different stages that individuals go through in their behavior change, including:
1. Precontemplation stage: When an individual has no intention to change their behavior within the next six months, they are in this stage (no intention to change).
2. Contemplation stage: An individual who intends to change their behavior within the next six months or has adopted the desired behavior for 24 hours is in this stage (considering a change).
3. Preparation stage: An individual in this stage intends to change their behavior within the next month and has also taken steps towards behavior change (creating small changes).
4. Action stage: An individual who has openly changed their behavior but has not passed more than six months since the change is in the action stage (actively engaging in the new behavior).
5. Maintenance stage: When more than six months have passed since an individual's apparent behavior change, they are in this stage (sustaining the change over time) (McKenzie et al., 2009) (Fig. 1).

After the Maintenance stage, two possible events can occur. The individual either enters the Termination stage, where they have 100% confidence in themselves and no temptation to relapse, or relapse occurs due to the temptation overpowering self-efficacy. In the Maintenance or Action stages, relapse can bring the individual back to any of the

Preparation, Contemplation, or Precontemplation stages, starting the process of change again (McKenzie et al., 2009).

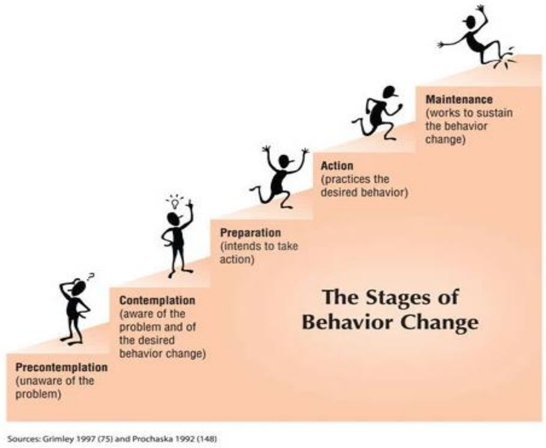

Fig. 1. The stages of behavior change of burning crop residues.

Decision balance

Decision balance refers to an individual's evaluation of the pros and cons of changing behavior. The focus of the decision balance framework is on the importance of the individual's positive (Pros) and negative (Cons) perceptions of behavior outcomes or behavior change. This framework assumes that individuals are unlikely to change their behavior unless they have a correct understanding of the superiority of the benefits over the barriers (Prochaska & Marcus, 1997).

Self-efficacy

Self-efficacy refers to an individual's belief in their ability to successfully perform a specific behavior. Self-efficacy is determined by individuals' confidence in avoiding risky behaviors or situations without relapsing to an unhealthy stage or risky behavior (McKenzie et al., 2009). It is an individual's estimation or internal belief in their capability to perform tasks. Self-efficacy is situation-dependent and varies for individuals depending on the environment.

Behavioral and cognitive process

The visible and covert activities that individuals engage into progress through the stages of change are called processes of change. These processes serve as useful guides for designing behavioral interventions for the target audience (McKenzie et al., 2009).

Education and non-burning of agricultural residues

A review of existing literature on agricultural education reveals that most studies focus primarily on formal and in-person training, with limited attention to virtual learning opportunities. However, research by Joshi et al. (2020) indicates that while virtual training in agriculture may present challenges like work-life imbalance and reduced social interaction, it can, according to McLellan (1998), provide a more relaxed and less stressful environment for learners. Furthermore, Jerković et al. (2022) found that virtual education reduces speaking anxiety among participants. Similarly, findings by Shi et al. (2023) highlight that virtual learning, through personalized experiences and diverse support services, can enhance educational access in rural areas. Additionally, research by Parjya and Srivastava (2021) demonstrates that virtual learning can positively impact learners' cognitive, emotional, behavioral, social, and participatory engagement, thereby contributing to their overall success. Research by Hongsachun et al. (2022) supports the idea that virtual education significantly enhances learners' self-efficacy. Zhang (2022) adds that self-efficacy in virtual learning is influenced by learner engagement. Meanwhile, Rahimi and Zilka (2023) report that virtual training can diminish social interactions and knowledge-sharing, which may reduce participants' self-efficacy. Complementing these findings, Bellhäuser et al. (2016) show that web-based training can substantially impact learners' knowledge, behavior, and self-regulated learning efficacy. Liu and Duan (2022) confirm that online learning environments can enhance cognitive engagement, with self-efficacy playing a mediating role. Additionally, Pitcher et al. (2022) suggest that high-immersion, high-fidelity virtual environments foster social learning dynamics, leading to improved professional self-efficacy and greater interest among participants.

In terms of sustainable residue management, Raza et al. (2019) demonstrate that raising farmers' awareness of sustainable residue management options can reduce the harmful effects of crop residue burning. Similarly, Reddy and Chhabra (2022) confirm that educating farmers on the negative impacts of burning crop residues can reduce its occurrence and enhance long-term crop sustainability. Ahmed et al. (2015) further reveals that farmers often burn residues due to cost-related challenges, but when informed about the visible and hidden benefits, they are more likely to choose alternatives to burning. Vickberg’s (1999) findings indicate that education can promote behavioral change by enhancing individuals' understanding of the benefits and drawbacks of their actions. This body of research underscores the potential of virtual education to facilitate self-efficacy and sustainable practices in agriculture, advocating for an expanded role for virtual learning in agricultural training programs.

MATERIALS AND METHODS

Study area

This research is geographically limited to the city of Ravansar, located in Kermanshah province, at 34 degrees 31 minutes’ north latitude and 46 degrees 21 minutes’ east longitude. Ravansar has a population of 77,657 and covers an area of 1,140 square kilometers. The city has 60,000 hectares of agricultural land, 1,475 hectares of orchards, and 4,000 wheat farmers. According to the latest national divisions, it consists of two districts: the central district (including Badr, Hassanabad, Dolatabad, and Zalvab) and the Shahou district (including Ghuri Ghaleh and Mansour Aghayi), with a total of 163 villages (Kermanshah Agricultural Profile, 2016) (Fig. 2).

Table 1. Comparison of behavioral models in terms of assessment constructs

	Perceived obstacles and Benefits	Past experiences	Self-efficacy	Environmental factors	Individual motivations	Subjective norms	Attitudes and beliefs
Reasoned Action Behavior Model (RABM)	✓	✓	✓	-	✓	✓	✓
Theory of Planned Behavior (TPB)	✓	✓	✓	-	✓	✓	✓
Social Exchange Theory (SET)	✓	-	-	✓	✓	-	✓
Fire-Motivation Theory Model (FMTM)	✓	✓	-	-	✓	✓	✓
Health Belief Model (HBM)	✓	✓	-	-	✓	✓	✓
Multi-Theory Model (MTM)	✓	✓	✓	✓	✓	✓	✓
Social Cognitive Theory (SCT)	✓	✓	✓	✓	✓	✓	✓
Protection Motivation Theory (PMT)	✓	✓	-	✓	✓	✓	✓
Norm Activation Model (NAM)	✓	-	-	✓	✓	✓	✓
Extended Parallel Process Model (EPPM)	✓	✓	-	✓	✓	✓	✓
Theory of Normative Social Behavior (TNSB)	✓	✓	-	✓	✓	✓	✓
Diffusion of Innovations Theory (DOI)	✓	✓	-	✓	✓	✓	✓
Cognitive-Affective-Behavioral (CAB) Model	✓	✓	-	-	✓	✓	✓
Transtheoretical Model (TTM)	✓	✓	✓	✓	✓	✓	✓

Research Findings Source (2024)

Table 2. Analysis of strengths and weaknesses of three comprehensive behavioral models

Behavioral models	Strength	Weakness
Transtheoretical Model (TTM)	It is a comprehensive and structured model that provides an understanding of the process of behavior change. It focuses on the stages of change and factors related to them (such as self-efficacy and individual needs). It has been proven effective in various cases of behavior change.	It may require specific questionnaires and complex measurements to be conducted. Some stages of change may be lengthy and complex.
Multi-Theory Model (MTM)	It includes multiple models and theories that have been integrated cohesively. It considers that various factors (such as environmental, psychological, and social) influence behavior. It is applicable in various fields.	Implementing and utilizing this model is complex and time-consuming. It requires knowledge and expertise about various models and theories.
Social Cognitive Theory (SCT)	Focus on psychological factors (such as self-efficacy, attitudes, and beliefs). Emphasize the impact of observation and modeling through sampling. It can pay attention to cognitive processes and individual thoughts.	Some psychological variables and processes are complex and difficult to measure. It may pay less attention to environmental and social factors.

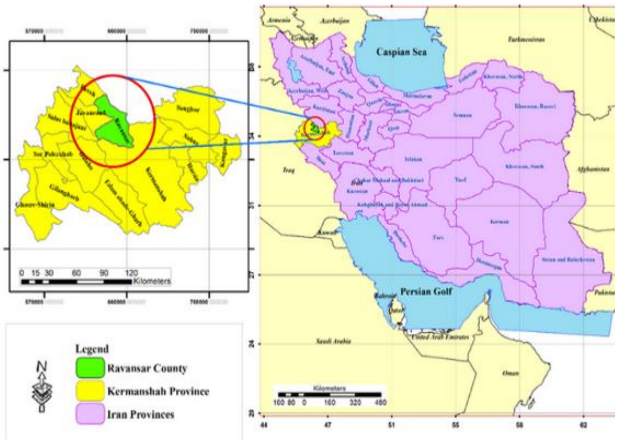

Fig. 2. The map of study area, Ravenscar County, Kermanshah province.

The present research is considered to be applied in terms of its objective and belongs to the category of quasi-experimental research in terms of research methodology.

Step 1: Determining participants (population, samples, and sampling method)

Initially, with the support of the Agricultural Jihad management in Ravansar, we discussed the research topic with the city manager and obtained permission to access wheat farmers' data through the Crop Statistics Unit's zoning system. After determining the number of wheat farmers by district, those owning less than 5 hectares of land were selected as the study population, totaling 400 individuals. On December 27, 2020, phone calls were made to 120 sampled individuals, followed by two meetings at the city management office to coordinate the process and clarify the research objectives and benefits. Participants were assured that all personal information would remain confidential and would not be shared with any external organizations.

Interviews with relevant experts revealed that crop residue burning is primarily conducted by wheat farmers who perform two crop cycles per year and own farms smaller than 5 hectares. Accordingly, to accurately measure and control the effects of training interventions, participants were screened based on these two criteria. A sample size of 180 was estimated, selected via simple random sampling and random number tables. The participants were then divided into two groups (control and remote training group), each comprising 60 individuals. Subsequently, a pre-test post-test design with a control group was implemented to assess the participants (Table 3).

Table 3. Experimental design

Study group	Pre-test	Intervention	Post-test
Experimental	O1	X1	O2
Control	O3	-	O4

X1 = virtual training

The data collection tool was a researcher-developed questionnaire based on the TTM of Change. To assess behavioral change, five questions were used to indicate the stages of precontemplation, contemplation, awareness, action, and maintenance, where respondents selected only one option matching their status. In the subsequent sections, which included self-efficacy, behavioral and cognitive processes, and decisional balance, a 5-point Likert scale (1 = very tow to 5 = very high) was employed. Descriptive statistics were used to analyze the collected data. To evaluate the significance of differences observed across behavioral change stages, the Kruskal-Wallis test was used. Since this study is quasi-experimental, efforts were made to homogenize the groups based on the control group and to control for confounding variables affecting the research outcomes. Formula 1 was applied to determine the net effect of virtual training. The results obtained were compared among each other and with the value in Formula 2, which reflects the influence of all unintended intervening variables and testing error (Naseri et al, as cited in Malek Mohammadi, 2024).

Formula 1: (O2 - O1) - (O4 - O3)
Formula 2: (O4 - O3)

Step 2. Grouping participants and conducting a pretest

In the next meeting, a researcher-developed questionnaire was designed in two sections. The first section covered the personal characteristics of the research participants, and the second section addressed the dimensions of behavior change stages, self-efficacy, situational self-sufficiency, decisional balance, and measured behavior. The same questionnaire was given to both the training group and the control group. On January 17, 2021, a pretest was conducted separately for the participants in the non-face-to-face training group, and on January 19, 2021, a pretest was conducted for the control group.

Step 3: Training for the study groups separately

The contact numbers of the participants in the non-face-to-face training group, previously obtained from the zoning system, were stored, and a training group named "Kah o Kelash Management" was formed on Telegram, and individuals became members of the group (Fig. 3). By mutual agreement, based on the most suitable time for the participants, which was agreed upon by 80% of the learners, four 30-minute sessions were conducted from 22:00 to 22:30, during which the materials were provided to the group members.

Fig. 3. Telegram group for residue and straw management and sample content presented in remote training.

In the remote training program, various aspects of sustainable agriculture practices were introduced over four sessions. The first session covered the disadvantages of traditional tillage methods, highlighting their negative impact on soil structure and fertility. In the second session, participants learned about alternative uses for crop residues, emphasizing ways to repurpose these materials rather than burning them. The third session explored the advantages of conservation tillage, discussing how this practice can enhance soil health, improve moisture retention, and reduce erosion. In the fourth and final session, the benefits of returning crop residues to the soil were outlined, along with detailed guidelines for effective implementation. Additionally, specific training on avoiding the burning of agricultural residues was provided, underscoring both environmental and soil health benefits. These sessions were scheduled in alignment with the virtual training dates for research participants (Table 4).

Step Four: Conducting the post-test

After 6 months of training, on July 17, 2021, a post-test was administered to the remote training group, while on July 19, 2021, the control group also underwent the post-test. It is worth mentioning that the research was planned and implemented in a way to prevent contact between individuals from different groups from taking place.

Table 4. Research implementation Process

Number of sessions	Content taught in each session	Teaching method	Educational materials used	Duration of instruction (in minutes)
1	Disadvantages of tillage	Chat (text)	Written content, photos, mobile phones, and the WhatsApp application	30
2	Various applications of residues	Chat (text)	Written content, photos, mobile phones, and the WhatsApp application	30
3	Advantages of conservation tillage	Chat (text)	Written content, photos, mobile phones, and the WhatsApp application	30
4	Benefits of returning residues to the soil	Chat (text)	Written content, photos, mobile phones, and the WhatsApp application	30

Source: Research Findings (2024)

Validity and reliability

The validity of a research tool refers to its ability to accurately measure the intended properties or characteristics. In this study, the validity of the questionnaire was ensured through a rigorous process. Firstly, the questionnaire was reviewed and revised by six experts from the Faculty of Agriculture Extension Panel at Razi University in Kermanshah and ten experienced professionals from the Promotion and Agriculture Deputy of the Agricultural Jihad Organization in the province. Their expertise and insights helped refine the questionnaire, and any phrases that were not suitable for farmers were replaced with simpler language. This review process ensured that the questionnaire effectively measured the intended variables and was appropriate for the target population.

In addition to validity, the reliability of the research tool was also assessed. One commonly used method to assess reliability is Cronbach's alpha coefficient. By conducting a thorough review process and calculating Cronbach's alpha, the researchers ensured both the validity and reliability of the questionnaire, thus enhancing the overall quality and credibility of the study (Table 5).

Table 5. Sample items and reliabilities of the TTM Scale

Scale	Descriptions	Number of items	Alpha
Decision balance - Pros - Cons	“Profit of change” “Cons of change”	22	0.91
Stage of change Precontemplation (PC) Contemplation (C) Preparation (P) Action (A) Maintenance (M)	“Not thinking of quitting burning residue in the 6 months” “Thinking of quitting burning residue in the 6 months” “Thinking of taking action within the past 6 months” “Thinking of taking action within 30 days” “Behavior change more than 6 months”	---	---
Self-efficacy	Self-confidence to maintain sustainable behavior when facing temptation in trying situations.	16	0.77
Behavioral and cognitive process Experimental 1. Consciousness Raising 2. Dramatic Relief 3.Environmental Reevaluation 4. Social Liberation 5. Self-Reevaluation Behavioral 1. Stimulus Control 2. Helping Relationship 3. Counter Condition 4.Reinforcement management 5. Self-Liberation	“I recall information farmers had given me on how to stop burning residue crops” “I react emotionally to warning about burning residue crops” “I consider the view that burning residue crops can be harmful to the environment” “I find society changing in ways that make it easier for the sustainable farmers” “My dependency on burning residue crops makes me feel disappointed in myself” “I remove things from my hand that remind me of burning residue crop” “I have someone who listens when I need to talk about my burning residue crop” “I find that doing other things with my crop is a good substitute for burning” “I reward myself when I do not burn residue crop” “I make commitments not to burn residue crop”	18	0.87

RESULTS

The results showed that all individuals in the control group and 85% of the experimental group were married, while only 15% of participants in the remote training group were single. Notably, the experimental group exhibited a significantly lower average age (45 years) compared to the control group (average age of 59 years). Additionally, the agricultural experience of the experimental group (mean: 23.35) was found to be lower than that of the control group (mean: 35.82). Furthermore, a closer examination of educational attainment demonstrated that both groups had comparable educational levels, with approximately 75% of participants in each group holding below-diploma qualifications. Additionally, over 80% of individuals in both groups were found to possess personal ownership, as a variable related to ownership. In Fig. 4, the stages of behavior change before and after training on crop residue management in the virtual group are presented. As shown, the number of individuals at each stage of behavior change did not exhibit a significant difference before and after the intervention. However, as seen in Fig. 5, the virtual training group experienced a shift, with more individuals moving towards sustaining and maintaining the desired behavior post-intervention.

Based on the finding, the stages of behavior change among participants in control and virtual groups, both before and after intervention, were analyzed. The ranking averages show that prior to the intervention, there was no significant difference in behavior change stages between the two groups. In the "Precontemplation" stage, the control group had lower average ranks in behavioral and cognitive processes and decision balance, while self-efficacy was higher in this group compared to the virtual group. In the "Preparation" stage, the decision balance indicator in the virtual group was significantly higher than that of the control group (Table 6). Following the intervention, notable differences emerged between the two groups. In the "Precontemplation" stage, self-efficacy in the virtual group significantly improved to an average of 40.37 compared to the control group. The virtual group also showed relative increases in ranking averages in the "Preparation" and "Action" stages, indicating a positive intervention effect. Furthermore, in the "Maintenance" stage, results show a slight increase in the virtual group's averages post-intervention. From a statistical perspective, Kruskal-Wallis and chi-square test results show that before the intervention, the Sig values across all indicators were above 0.05, indicating no significant difference between the groups. Specifically, prior to intervention, the chi-square statistics for behavioral and cognitive processes (1.648), decision balance (4.727), and self-efficacy (8.271) each had Sig values over 0.05, demonstrating a lack of significant difference between the groups. However, post-intervention, decision balance and self-efficacy indicators in the virtual group reached a significant level. Chi-square values for decision balance (9.899) and self-efficacy (11.077) showed Sig values of 0.042 and 0.026, respectively, both below 0.05. This suggests a significant positive effect of the virtual intervention on these indicators (Table 7).

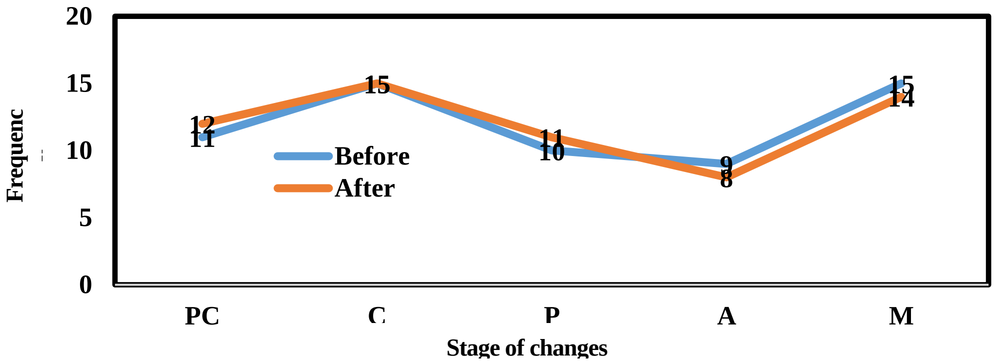

Fig. 4. Changes in agricultural residue burning behavior in the control group: A pre- and post-intervention comparison. Precontemplation (PC), Contemplation (C), Preparation (P), Action (A), Maintenance (M).

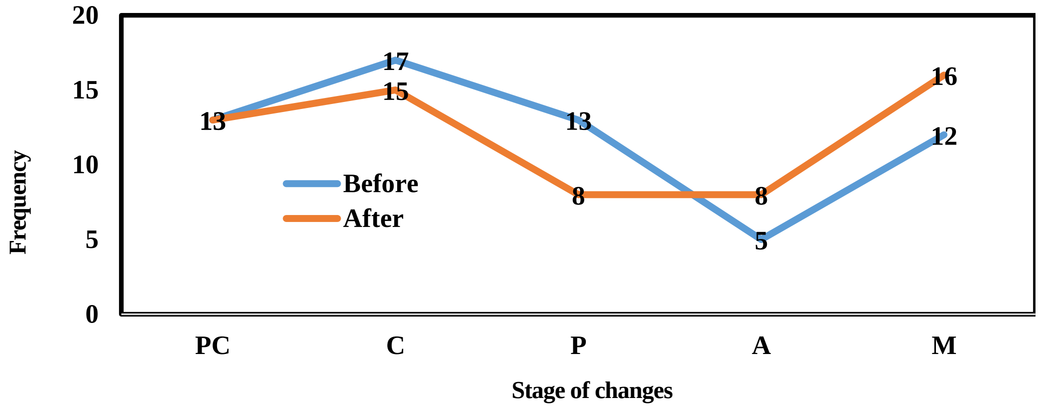

Fig. 5. Changes in agricultural residue burning behavior in the virtual group: A pre- and post-intervention comparison. Precontemplation (PC), Contemplation (C), Preparation (P), Action (A), Maintenance (M)

Table 6. Status of behavior change stages among participants before intervention

Stage of change	Average rank of behavioral and cognitive process		Average rank of decision balance		Average rank of self-efficacy	
	Control	Virtual	Control	Virtual	Control	Virtual
PC	25.77	32.58	33.00	34.08	39.77	32.58
C	29.60	29.35	25.10	29.76	33.00	28.03
P	26.45	31.00	27.75	60.67	27.45	38.23
A	32.83	18.30	33.06	22.00	22.22	24.50
M	32.58	34.42	30.50	26.50	23.38	25.58
Kruskal-Wallis	1.648	3.313	4.727	3.736	8.271	4.667
df	4	4	4	4	4	4
Sig	0.800	0.507	0.316	0.443	0.082	0.323

Precontemplation (PC), Contemplation (C), Preparation (P), Action (A), Maintenance (M), Degree of freedom (df), Significant (Sig)

Table 7. Status of behavior change stages among participants after intervention

Stage of change	Average rank of behavioral and cognitive process		Average rank of decision balance		Average rank of self-efficacy	
	Control	Virtual	Control	Virtual	Control	Virtual
PC	29.63	25.92	24.63	24.27	26.25	40.37
C	27.00	29.40	26.96	26.64	29.93	35.00
P	30.41	33.56	34.40	27.13	35.68	19.44
A	33.81	34.13	33.44	34.43	36.38	21.75
M	33.18	31.91	30.46	35.28	27.32	27.88
Kruskal-Wallis	1.251	1.650	4.266	9.899	3.067	11.077
df	4	4	4	4	4	4
Sig	0.870	0.800	0.371	0.042	0.547	0.026

Precontemplation (PC), Contemplation (C), Preparation (P), Action (A), Maintenance (M), Degree of freedom (df), Significant (Sig)

DISCUSSION

The comparison of results between the experimental and control groups highlights that virtual training significantly impacted participants' behavior-change stages, decision balance, and self-efficacy. However, the virtual training did not create substantial shifts in participants' cognitive-behavioral processes. These findings support Vickberg's (1999) assertion that education, by enhancing individuals' understanding of the pros and cons of specific behaviors, can promote transitions in behavior-change stages. Furthermore, this study's findings revealed that virtual training successfully increased participants' self-efficacy, encouraging them to avoid burning crop residues. Similar results have been reported by Hsiao (2021) and Hongsuchon et al. (2022), who concluded that web-based education significantly boosts learners' self-efficacy and behavior towards sustainable practices. Bellhäuser et al. (2016) also found that online training significantly impacts knowledge, behavior, and self-regulated learning efficacy, supporting the notion that online learning environments can enhance individual cognitive engagement through self-efficacy as a mediating factor (Liu & Duan, 2022). Additionally, Pitcher et al. (2022) observed that immersive, high-fidelity virtual educational environments, through fostering social learning dynamics, lead to improved professional self-efficacy and greater engagement. The present findings suggest that virtual training successfully communicated the advantages of avoiding crop residue burning, thus raising participants' awareness and improving decision balance. These results align with Raza et al. (2019), who found that increasing farmers' awareness of sustainable residue management options can mitigate the negative impacts of burning crop residues. Similarly, Reddy and Chhabra (2022) emphasize that educating farmers on the harmful effects of crop residue burning helps reduce its prevalence and promotes long-term crop sustainability. Ahmed et al. (2015) also explored farmers' motivations, indicating that while economic constraints drive residue burning, awareness of hidden and explicit benefits from alternative practices can shift their behavior towards more sustainable management. Despite these positive impacts, virtual training did not induce significant cognitive or behavioral process changes among participants. This suggests that behavior change may require additional time and experiential reinforcement. Continuous practice and adherence to residue management techniques over time could lead to more profound cognitive and behavioral shifts, equipping farmers with the knowledge and experience needed to advocate for non-burning practices among their peers. Over time, as farmers solidify these behaviors, the sustainability benefits of crop residue management may become more ingrained, ultimately fostering broader adoption across the agricultural community.

In conducting any research, there are limitations and obstacles to consider. One of the major limitations of this research was the lack of similar studies and literature specifically related to the application of the behavior change model in the field of agriculture. This issue posed challenges for researchers in terms of findings and discussions. Additionally, the weak internet connectivity in some rural areas and the untimely presence of some participants hindered the smooth progress of the classes, causing delays and sluggishness. Another limitation of this research was the inability to implement a complete experimental research design. Due to time constraints and budget limitations, researchers were unable to execute this method.

For policymakers, the findings of this study have important implications for the design and implementation of virtual learning programs aimed at promoting behavior change. Virtual learning environments have limitations that can hinder behavior change, such as the lack of learner-instructor relationships and learner-to-learner interaction. Therefore, policymakers should prioritize addressing these limitations by investing in technologies and infrastructure that support effective virtual learning experiences. Additionally, policymakers should consider the importance of raising awareness and understanding of the benefits associated with the desired behavior. This can be achieved through targeted educational campaigns and information dissemination, highlighting the advantages and positive outcomes of behavior change. By emphasizing the benefits, policymakers can motivate individuals to actively engage in behavior change efforts. The study also highlights the significant positive impact of virtual training on self-efficacy and the process of change. This indicates that policy makers should promote the integration of virtual technologies and e-learning methods into behavior change programs. Providing resources and support for the development and implementation of virtual training modules can enhance the effectiveness and efficiency of behavior change interventions. However, it is important to note that virtual training did not significantly affect individuals' decisional balance. Policymakers should explore strategies to address this issue, such as conducting targeted assessments to identify the underlying factors that may hinder the establishment of decisional balance. By understanding these factors, policies, and interventions can be developed to better address participants' motivations and decision-making processes.

CONCLUSION

The present study demonstrated that virtual education based on the TTM model could create a new path in distance education regarding self-efficacy, decision balance, and stage of change in agriculture. Therefore, the traditional view of agricultural education needs to change, and virtual education should be utilized as a complementary approach to formal education. Paying attention to these types of education, as they eliminate temporal and spatial boundaries, can offer numerous advantages to farmers. Literature review show that distance and open education can be an effective and cost-efficient tools for providing mass access to the necessary skills and technical expertise. Moreover, the results of this research expanded the application of the TTM model, demonstrating that its application is not limited to the fields of health and psychological pathology. Instead, it can be used to enhance environmental psychological behaviors such as agricultural residue management.

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DECLARATION OF COMPETING INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY

The data presented in this study are available on request from the corresponding author.

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