

Improving Farmers' Perception and Use of Climate Predictions in Farming Decisions: A Transition Model

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ABSTRACT

Despite tremendous efforts to improve weather and climate predictions and to inform farmers about the use of such weather products, farmers' attitudes toward forecast use remain poor and farmer use of forecasts has not increased. This paper describes features of a new conceptual model for facilitating farmers' use of weather products and offers preliminary evidence for its effectiveness based on a test-of-concept prototype. The prototype system provides farmers with contextualized information, the opportunity to use that information in relevant farming contexts, and collaborative interaction with other users. In addition, scaffolding and feedback are incorporated in the model to enhance learning and motivation. Surveys before and after use of the prototype system, and focus-group discussion after system use, were conducted to obtain evaluations from 15 farmers in southeastern Nebraska. Farmers' evaluations of the system were moderately positive and indicated greater intentions to use the products in the future than they had in the past. However, farmers only slightly increased their positive expectancies of various general categories of weather and climate products, supporting the difficulties associated with changing overall attitudes when attempting to transfer scientific improvements into practical uses. It is suggested that multiple exposures to such a system and more individualized and personally relevant use opportunities may further enhance the power of the proposed model.

1. Introduction

Tremendous effort and expense have been put into improving the accuracy, readability, and applicability

of weather and climate predictions, and most experts would agree that these weather and climate forecasts can benefit agricultural production if used effectively. However, despite correspondingly tremendous efforts to inform farmers about the availability and potential usefulness of such products (HPRCC 1994), farmers' attitudes toward and use of weather and climate forecasts have changed little over the decades (Rayner et al.

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2005; Vogel and O'Brien 2006; Millner 2008). This lack of change points to a need for new and more effective methods for transferring improved weather and climate products into applications to benefit farming decisions.

Current approaches typically present weather product information to farmers in contexts separate from farmer day-to-day activities and actual experiences (e.g., in workshops and informational publications). These approaches, as suggested by contemporary learning and motivation theories, have three drawbacks. First, decontextualized information dissemination does not promote learning that generalizes to specific contexts. Learning-by-doing theories [e.g., situated learning theory; see Anderson et al. (1996) for a critical review], in particular, underscore the inextricable relationship among learning, motivation (e.g., intention), and *context*. As noted by Putnam and Borko (2000, p. 4),

Early cognitive theories typically treated . . . learning as the acquisition of knowledge and skills thought to be useful in a wide variety of settings Situative theorists challenge this assumption of a cognitive core independent of context and intention They posit, instead, that the physical and social contexts in which an activity takes place are an integral part of the activity, and that the activity is an integral part of the learning that takes place within it.

Second, when information dissemination is not accompanied by experience and practice, not only is learning undermined, so is motivation. For example, according to the theory of planned behavior and theory of reasoned action (Ajzen 1991, 2001; see also Bandura 1994, 1997, and the discussion in Hu et al. 2006), personal experiences can affect farmers' beliefs about the utility of the predictions for certain outcomes (i.e., their outcome expectancies) and change their attitudes and motivation to use the predictions in decisions. Third, constructivist (e.g., Piaget 1932; Vygotsky 1978) and other approaches suggest that motivation to use knowledge and information is most enhanced when people "own" and actively contribute to that knowledge and information, rather than having it merely presented to them. McCown (2005), for example, suggests that farmers must, through personal experience in relevant contexts, come to their own understanding of weather predictions because farmers are reluctant to use information in their decision making unless that information is generated from *their own* experience.

Consideration of learning and motivation theories suggests that new and more effective transition models would include *contextualized information*, *personal experience* using that information, and *collaborative interaction* that contributes to that information. In this paper we briefly describe the design and preliminary testing of a

model including these features through the use of a test-of-concept prototype. The prototype implements these features and also incorporates *scaffolding* and *feedback*, two additional important features of educational design.

2. A prototype of a new model and method

The structure and flow of our prototype are illustrated in Fig. 1. For ease of access and to enhance its potential scalability, the demonstration prototype is Web based (online at <http://driftwood.unl.edu/farmsmart>).

a. Resources: Providing access to contextualized information

A major component of the prototype is the resources section, where users have access to a list of products, additional informational resources about the products, and links to any of the products that have a Web presence ("Resources" in Fig. 1). These informational resources also include how to navigate each product's Web site to locate specific predictions and historical archives, how to read and interpret the product, and how to use it or limitations of its use in various types of farming decisions. Albeit we have already argued that "information provision" is not sufficient to ensure its use, a key feature of the resources in this model is that they are linked to case scenarios in which the information might be useful, thereby providing *contextualized information*. Provision of such resources is important because farmers are often faced with numerous, conflicting sources of climate and weather information and are left to wonder which sources they should trust in making specific decisions (Hu et al. 2006) or how to find and interpret information useful for specific situations. Provision of trustworthy and clear information can ease access and improve understanding of weather products and has been regarded as having an important influence on farmers' personal attitudes about particular forecasts as well as being important for enhancing their general forecast use (Artikov et al. 2006).

b. Case scenarios: Opportunities for building personal experience

Within the Web-based prototype, farmers can visit an area called ThinkAboutIt (TAI), which presents case scenarios involving weather product information and decision-making opportunities. TAI is a Web-based technology (composed of the components inside the dashed-line box in Fig. 1) developed at the University of Nebraska at Lincoln to teach critical thinking. We chose to use case scenarios to provide farmers opportunities to build personal experience and practice applying weather products to specific situations based on a large body of literature on case methods. Case methods involve authentic, real

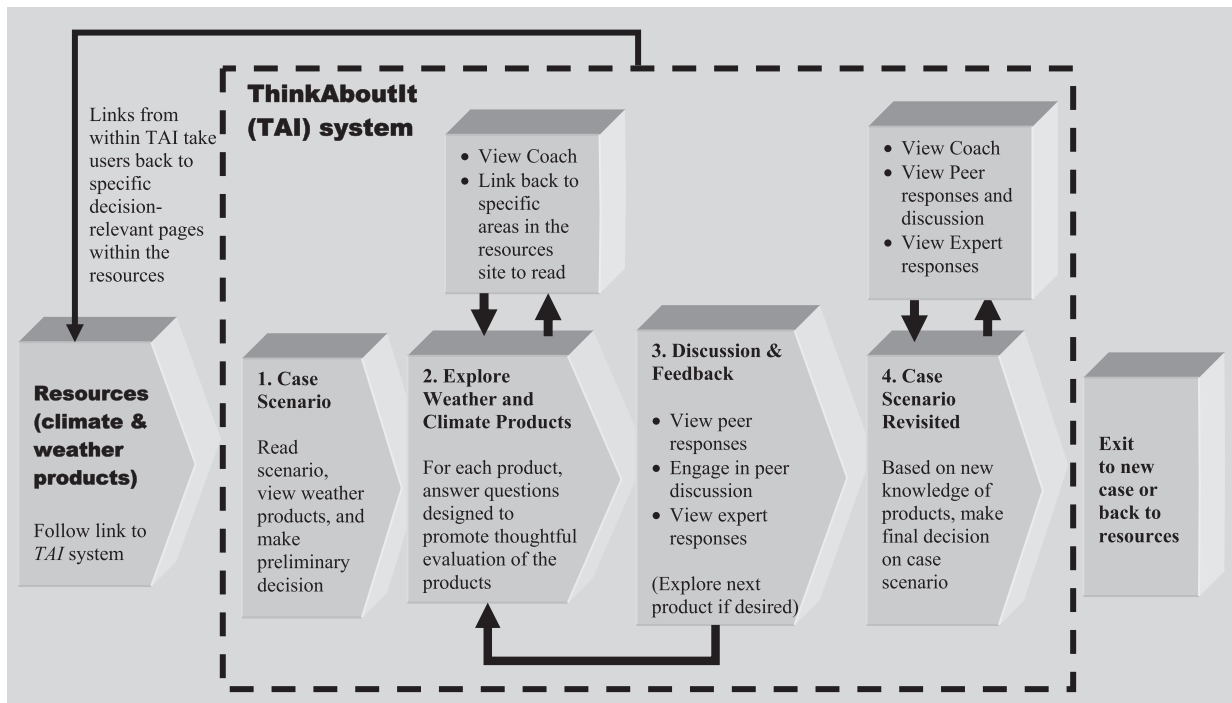


FIG. 1. A schematic of the prototype system.

decisions, accompanied by opportunity for reflection and feedback, and have been employed as an efficient supplement to apprenticeship training in numerous professions (e.g., Bruning et al. 2008; Greenwood 2000). In addition to involving realistic problem-solving situations (i.e., case scenarios), low-stakes learning opportunities, and careful individual or shared reflection among peers (e.g., Merseeth 1991; McDade 1995; Kreber 2001), use of case methods has been found to relate to enhanced critical thinking, transfer of learning, and improved motivation (Bruning et al. 2008; Enos et al. 2003; McDade 1995; PytlikZillig et al. 2009, manuscript submitted to *J. Educ. Psychol.*; Stolovitch and Yapi 1997).

In our prototype scenario, we describe a practical, real-world farming irrigation decision. The scenario was written and revised based on critiques by farmers, extension agents, and crop consultants both from within and outside of the location featured in the case study (in our example, Franklin County, Nebraska). The final version of the prototype scenario describes the location, planting date, irrigation costs, and climate conditions since planting and asks farmers to make an irrigation decision using information from relevant weather products.

c. Discussion: A forum for collaborative interaction

Within the TAI tool, after farmers read and respond to the case scenario, they are given the opportunity to

explore weather products in more detail (Fig. 1; TAI component 2) and are invited to answer at least four questions for each product. One multiple-choice question concerns the interpretation of the prediction or product, for example, “According to the 5-day Precipitation Forecast map, what is the predicted rainfall in your area over the next five days?” Another asks farmers to rate the usefulness of the information in the prediction to the decision-making case scenario, for example: “How useful is this information for making the case scenario decision?” Most important is that these two closed-ended questions are each paired with open-ended questions that allow farmers to contribute their opinions and expertise and to launch discussions with other users (Fig. 1; TAI component 3). To be specific, after the forecast interpretation question, users are asked to think critically and offer suggestions regarding how the presentation of the forecast can be improved for their use. In a similar way, after rating the usefulness of a weather product for making the case scenario decision, farmers are asked to justify and explain their rating relative to the specific case scenario context.

As discussed in section 2d, farmers do receive feedback on their answers to the questions. However, at this point it is important to note that a key feature of the design of the questions was that they solicited both farmer input and ownership of the knowledge they were creating and they engaged farmers in discussion with their peers. Farmer input and explanations are essential for enhancing their

ownership of the new knowledge they are developing. In addition, explanation also can facilitate the learning of new skills, deeper learning, and better integration of new knowledge with prior knowledge (Ainsworth and Loizou 2003; Chi et al. 1989, 1994; Renkl 2002; Roscoe and Chi 2008; Roy and Chi 2005). Meanwhile, peer discussion can enhance many important outcomes, including understanding, critical thinking, and construction of complex knowledge (Gunawardena et al. 1997; Newman et al. 1997; Thomas 2002). Peer discussion also can create a social environment that can affect attitudes toward the use of the weather products. When respected peers accept and value the use of certain weather products for certain farming decisions, they also impact others' attitudes toward the products (Ajzen 1985).

d. Coaching and others' opinions: Scaffolding and feedback

Scaffolding and feedback are other important features of educational design incorporated into the model prototype. *Scaffolding* refers to supporting learners as they form new knowledge by providing guidance, and then gradually removing that support as learners gain experience with the tasks (Vygotsky 1978; Brown et al. 1989; Pea 2004). In our model, scaffolding is primarily provided in "coaching" within TAI. While users explore the weather products within the context of the case scenario administered by the TAI tool, a digital *coach* is available to provide context-specific hints and guidance whenever the user wants or needs it. The coach does not give the answers to the questions posed to the farmers but does bring up information about a specified forecast as well as a link back to the specific part of the resources that provides additional information. Some of the coaching information includes how to read and interpret the products, how to find the right information for specific locations and times of interest, and how the products might be applied in various farming operations.

In our prototype, feedback within TAI comes from both peers and experts. Upon answering a pair of questions (one closed and one open ended), users not only see their peers' open-ended comments for discussion, but also are presented with a statistical and graphical display (a bar chart) of peer responses to the closed-ended question. This feedback is useful for affirming matching responses in the case in which one finds that most of his/her peers agree or disagree with his/her answer, for creating cognitive dissonance or disequilibrium that the producers are then motivated to resolve (de Lisi and Golbeck 1999). Users also are provided with *expert feedback* after each pair of questions. The "expert" provides a "best choice" answer to each question that is actually a composite answer constructed based on the judgments of experts, crop

consultants, extension agents, and researchers. Users can bring up the expert opinion, which includes both what experts had judged as the best answer to the multiple-choice question and also the experts' rationale (open-ended explanation) for the answer, so that users can compare this feedback with their own answers and explanations. From a learning perspective, such feedback has been shown to be important for helping learners to build competence and increase their self-efficacy (e.g., McCarthy et al. 1995; Schunk and Rice 1993). In addition, by explaining the rationale for the answer, the expert provides learners with a "cognitive apprenticeship" that can help users to understand better how to think critically about issues relevant to effectively using weather information in decision making (Pedersen and Liu 2002).

3. Encouraging evidence from focus group surveys and discussion

To assess our preliminary test of concept, we presented the prototype to focus groups composed of farmers from south-central Nebraska. The two focus groups had 6 and 9 participants each, and 14 of them were male. Their ages ranged from 27 to 59 (average 44.5). They each reported 10–40 years of farming experience from 1000 to over 2000 acres of crop lands, most of which were irrigated.¹ Thus, irrigation decisions such as whether, when, and how much to irrigate during the growing season were important to these participants. Most of them also indicated that they had computers at home; however, there was great variability in familiarity with and extent of computer use.

Members of each focus group completed a presurvey and then spent approximately 2 h exploring the system. They first were introduced to the prototype system by the researchers and then explored the system on their own. After exploring the system, users completed an anonymous postsurvey. Some questions in the postsurvey were identical to those in the presurvey to assess changes in farmers' attitudes toward weather products (both generally and for specific products). Other questions asked for farmers to report the extent to which they had used weather products in the past (in general, as well as specific products used in the scenario) and the extent to which they intended to use them in the future. Following the

¹ For this study, we sought farmers who irrigated and would thus be faced with irrigation decisions. Relative to the farmers in the larger-scale study of Hu et al. (2006), which also examined farmers in southeastern Nebraska, members of the sample presented in this paper were younger and farmed and irrigated more acres. The participants in the 2006 study were aged 19–92 (average age 52), averaged 30 years of farming experience, and farmed an average of 781 acres, with less than one-half of those irrigated.

postsurvey, researchers led the participants in a large group discussion, asking them to share their reactions to and impressions of the system and each of its components. Participants were specifically asked what they liked, disliked, felt was effective, or felt needed improvement. Results of these surveys and interactions are summarized below.

a. System evaluation

Evaluations of specific model features, including the decision-making scenarios, coaching, expert feedback, peer-discussion area, and resources, were generally positive (see Table 1) but also showed room for improvement. On a 0–6 scale, almost all mean ratings of system features are above the scale midpoint (3.0) except use of the resources (2.77). Thus, participants reported using and exploring the novel features of coaching, expert feedback, and peer discussion more than the informational resources. Farmers valued the expert/consultant materials highest and rated them as the most helpful and informative components of the model. Because the expert/consultant materials give specific details about how individual climate products can or should be used in making a specific decision, these high ratings may indicate farmers’ strong interest in and need for expert information concerning the application of weather products in specific situations. This interpretation was supported by the discussion among the focus groups after they had used the system, during which a number of farmers indicated they would like to have the discussion area include interaction with experts concerning questions related to their specific farms and fields.

b. Change in expectancies

To assess weather product–relevant expectancies before and after use of the model, participants were asked, “In your opinion, *how likely* is it that each of the following [general] weather forecasts and information are any good at producing the following outcomes?” One question asked participants to rate the likelihood that “precipitation forecasts are good for helping you to maximize profit.” Table 2 shows the average pre- and postanswers of the participants for the surveyed forecast–outcome combinations. The means in Table 2 show an interesting pattern of all positive changes (except for one item) in farmer outcome expectancies. The consistency of the increases over such a short time span and only one exposure to a prototype of the model argues for a potentially positive impact of this method of education/training on farmers’ beliefs, and therefore their attitudes about forecasts. Nonetheless, the effect sizes of the increases were small and not statistically significant when tested in our small sample. The very modest effect

TABLE 1. Evaluations of transition-module components (ratings were made using a scale from 0 = “not at all” to 6 = “very much”). Here *N* is the number of participants; Min and Max are minimum and maximum rating to the question, respectively; *M* and SD are mean and standard deviation of the rating data, respectively; and Cov is the standard deviation divided by the mean.

Module ratings	<i>N</i>	Min	Max	<i>M</i>	SD	Cov
Scenario/TAI questions						
Clear/understandable	15	3	6	4.00	1.00	0.25
Realistic	15	2	6	4.20	1.08	0.26
Avg	15	3.00	5.50	4.10	0.78	0.19
Coach						
Extent of use	13	1	5	3.15	1.14	0.36
Clear/understandable	15	3	5	4.33	0.62	0.14
Helpful	15	2	5	3.93	1.03	0.26
Informative	15	2	5	4.07	0.88	0.22
Avg	15	2.50	5.00	3.89	0.72	0.19
Consultant						
Extent of use	14	1	6	3.79	1.48	0.39
Clear/understandable	15	2	6	4.40	0.91	0.21
Helpful	15	3	6	4.40	0.91	0.21
Informative	15	3	6	4.47	0.92	0.20
Avg	15	2.25	5.67	4.29	0.90	0.21
Resources						
Extent of use	13	0	4	2.77	1.30	0.47
Clear/understandable	14	2	5	3.86	0.86	0.22
Helpful	14	3	5	3.86	0.66	0.17
Informative	14	3	5	4.07	0.73	0.18
Avg	14	2.50	4.50	3.66	0.66	0.18
Discussion area						
Extent of use	12	0	6	3.17	1.80	0.57
Clear/understandable	13	3	6	4.08	1.12	0.27
Helpful	13	0	6	3.15	1.57	0.50
Informative	13	1	6	3.62	1.26	0.35
Avg	14	0.00	6.00	3.31	1.36	0.41

sizes might indicate the difficulty in changing farmer attitudes toward general categories of products, especially with only one exposure to a system. For example, a number of cognitive biases might be at work against such attitude changes, including confirmation biases—tendencies to give greater weight to information that is consistent with one’s beliefs and to discount evidence that is inconsistent (see Slovic 1987; Nickerson 1998). As an alternative, system users may not have felt the scenario decision was as significant as those they face and “own” in real life. Farmer comments after using the system did again suggest that farmers were more interested in *specific* information—including information from specific products and specific to their own farms and fields.

c. Willingness to use weather products and predictions

Prior to interacting with the training system, participants saw the name and a picture of each specific weather and climate product/prediction that would be

TABLE 2. Pre- and postanswers to the question, How likely it is that weather products will produce various outcomes? (0 = extremely unlikely, 3 = moderately likely, 6 = extremely likely). Here, η^2 is a measure of effect size similar to R^2 and Pwr is the observed power of the analyses, i.e., the probability of finding a significant effect given the size of the effect and the number of participants; p is the two-tailed significance level.

Outcome expectancies	Preanswer			Postanswer			Change			
	<i>M</i>	SD	Cov	<i>M</i>	SD	Cov	<i>M</i>	<i>p</i>	η^2	Pwr
Precipitation forecasts										
Preserve environment	3.67	1.23	0.34	3.73	1.10	0.29	+0.06	0.75	0.01	0.06
Save water	3.47	0.99	0.29	4.00	0.85	0.21	+0.53	0.04	0.27	0.56
Maximize profit	4.53	0.92	0.20	4.73	0.80	0.17	+0.20	0.19	0.12	0.25
Control over farming	4.40	1.18	0.27	4.40	0.83	0.19	0.00	1.0	0	0.05
Temperature forecasts										
Preserve environment	3.20	1.21	0.38	3.67	1.18	0.32	+0.47	0.13	0.16	0.32
Save water	3.27	0.96	0.29	3.80	0.94	0.25	+0.53	0.14	0.15	0.32
Maximize profit	4.13	1.25	0.30	4.53	0.83	0.18	+0.40	0.16	0.13	0.28
Control over farming	4.13	1.41	0.34	4.40	0.91	0.21	+0.27	0.36	0.06	0.14
Wind forecasts										
Preserve environment	3.67	1.23	0.34	3.80	1.15	0.30	+0.13	0.55	0.03	0.09
Save water	3.20	0.94	0.29	3.53	1.13	0.32	+0.33	0.31	0.07	0.16
Maximize profit	4.00	1.41	0.35	4.40	0.91	0.21	+0.40	0.16	0.13	0.28
Control over farming	3.80	1.78	0.47	4.20	1.01	0.24	+0.40	0.23	0.10	0.21

available for use in the system and were asked to rate the extent to which they have allowed it to influence their decisions in the past. After going through the training, participants were asked the extent to which they intended to use those weather products in the future. Results in Table 3 show that the average ratings for postsurvey questions were significantly and substantially higher than that for the presurvey questions. These relatively large effects contrast with the small effects reported for general forecasts, and are consistent with the farmers' desire for and focus on specific products and information.

To assess the extent to which participants felt they had changed their willingness to use various forecasts in a more global sense, we asked them, "Compared to the last time you did this survey, please rate the extent to

which each of the following general types of weather forecasts and information will influence your irrigation decisions in the future." The ratings shown in Table 4 indicate that, on average, the participants would use the products/predictions slightly more. All answers fell into the 0–2 range on the scale from –3 to +3 and are statistically significant in single-tailed Student's *t* test comparing the mean with 0. However, the averages for each item were less than +1 on the scale from –3 to +3, indicating the perceived positive changes were small. Results in Table 4 indicate that the largest reported changes are in intention to use temperature and wind predictions. During focus-group discussions, farmer comments suggested that it was obvious to use precipitation products but use of temperature and wind products within the

TABLE 3. Rated past (pre) and intended future (post) influence of specific weather products and predictions on irrigation decisions. (Note: $N = 15$ in the "pre" and "post" surveys). For each data product and prediction, participants were asked to report how much they had used (or intended to use in the future) the product/prediction in irrigation decisions. Answer options ranged from 0 = never to 1 = seldom to 6 = "a great deal."

Weather products	Pre			Post			Difference			
	<i>M</i>	SD	Cov	<i>M</i>	SD	Cov	<i>M</i>	<i>p</i>	η^2	Pwr
High Plains Regional Climate Center (HPRCC) soil water content	1.47	1.69	1.15	2.93	1.22	0.42	+1.46	0.017	0.34	0.71
HPRCC soil water accumulation	1.60	1.84	1.15	3.33	1.18	0.35	+1.73	0.008	0.41	0.83
National Oceanic and Atmospheric Administration (NOAA) 5-day precipitation prediction	2.47	1.60	0.65	4.07	1.0	0.25	+1.60	<0.001	0.60	0.98
NOAA min and max temperature predictions	2.00	1.93	0.97	3.93	1.16	0.30	+1.93	0.002	0.52	0.95
NOAA wind predictions	1.60	1.72	1.08	3.87	1.19	0.31	+2.27	<0.001	0.63	1.0
NOAA meteorogram	0.27	0.80	2.96	3.27	1.49	0.46	+3.00	<0.001	0.77	1.0
Avg	1.57	1.17	0.75	3.57	0.91	0.25	+2.00	<0.001	0.69	1.0

TABLE 4. Ratings for the question, “Compared to before using FarmSmart and TAI, how much will different types of weather data products and predictions influence your production decisions in the future?” (rated on a scale ranging from $-3 =$ “a great deal less,” to $0 =$ the same as before, to $+3 =$ “a great deal more than before”).

Weather product	<i>N</i>	Min	Max	<i>M</i>	<i>SD</i>	<i>Cov</i>
Soil moisture content	14	0	2	0.57	0.65	1.13
Precipitation forecasts	14	0	2	0.86	0.86	1.00
Temperature forecasts	14	0	2	0.93	0.62	0.66
Wind predictions	14	0	2	0.93	0.62	0.66
Avg	14	0.00	1.80	0.82	0.69	0.84

scenario increased the salience of the relevance of these products for irrigation decisions, resulting in their increased willingness to use them in going from pre- to postexposure to the system.

4. Concluding remarks

To successfully transfer costly weather and climate products into meaningful information that farmers can use in their decisions, farmers must understand the products and have the skills and motivation to extract the relevant pieces of information and apply them to specific decision contexts. Based on consideration of educational and motivational theories, we contend that provision of contextualized information and opportunities for farmers to gain experience using the products and to contribute their own expertise to a situated knowledge base can enhance farmer knowledge and motivation to use the products in their decisions. In its emphasis on farmer input and contributions, our approach may be compared to other participatory approaches involving stakeholders in the creation of decision-making tools (e.g., Cabrera et al. 2008; Jagtap et al. 2002). However, our model places greater emphasis on principles of learning through practice and motivation. In addition, our model proposes the use of the Internet for all aspects of the model.

Preliminary test results of our model are encouraging. We cannot infer that these results, which are based on a small sample and the use of a single case scenario, represent generalizable conclusions applicable to other populations. However, the results are suggestive of the model’s promise. The most promising aspects of the model included feedback from experts and aspects most relevant to farmers’ own specific situations. Farmers’ desire for expert over peer feedback suggests that they may be looking for feedback that they find trustworthy, and that the role of farmer trust in the transition of weather information into actual use should be further explored in future research. In addition, although climate and weather predictions are far from being detailed

enough for specific locations where climate information may be desired, results from this study suggest that the effectiveness of the model might be most powerful if the case scenarios are designed to be maximally relevant to farmers’ specific and unique situations.

Results suggested that use of this model also may be most likely to immediately affect perceptions of the specific forecasts featured in the prototype, but not of general categories of forecasts. Given that the effects on general outcome expectancies were small, future work should examine the power of multiple exposures to these methods, especially in larger and more diverse samples and additional contexts. Further development and tests of this model and the implementation of refined and tested modules in various public domains such as regional climate centers have the potential to improve effective use of climate predictions in agricultural and other production decisions. Given the social importance of these decisions, the outcomes of which impact food availability, economics, the environment, and other areas, further development of such transition models is of immediate and substantial importance.

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REFERENCES

Ainsworth, S., and A. T. Loizou, 2003: The effects of self-explaining when learning with text or diagrams. *Cognit. Sci.*, **27**, 669–681.

Ajzen, I., 1985: From intentions to actions: A theory of planned behavior. *Action Control: From Cognition to Behavior*, J. Kuhl and J. Beckmann, Eds., Springer-Verlag, 11–39.

—, 1991: The theory of planned behavior. *Behav. Hum. Decis. Processes*, **50**, 179–211.

—, 2001: Nature and operation of attitudes. *Annu. Rev. Psychol.*, **52**, 27–58.

Anderson, J. R., L. M. Reder, and H. A. Simon, 1996: Situated learning and education. *Educ. Res.*, **25**, 5–11.

Artikov, I., and Coauthors, 2006: Understanding the influence of climate forecasts on farmer decisions as planned behavior. *J. Appl. Meteor. Climatol.*, **45**, 1202–1214.

Bandura, A., 1994: Self-efficacy. *Encyclopedia of Human Behavior*, Vol. 4, V. S. Ramachaudran, Ed., Academic Press, 71–81.

—, 1997: *Self-Efficacy: The Exercise of Control*. W. H. Freeman and Company, 604 pp.

Brown, J. S., A. Collins, and P. Duguid, 1989: Situated cognition and the culture of learning. *Educ. Res.*, **18**, 32–42.

- Bruning, R., K. O. Siwatu, X. Liu, L. M. PytlikZillig, C. Horn, S. Sic, and D. Carlson, 2008: Introducing teaching cases with face-to-face and computer-mediated discussion: Two multi-classroom quasi-experiments. *Contemp. Educ. Psychol.*, **33**, 299–326.
- Cabrera, V. E., N. E. Breuer, and P. E. Hildebrand, 2008: Participatory modeling in dairy farm systems: A method for building consensual environmental sustainability using seasonal climate forecasts. *Climatic Change*, **89**, 395–409.
- Chi, M. T. H., M. Bassok, M. Lewis, P. Reimann, and R. Glaser, 1989: Self-explanations: How students study and use examples in learning to solve problems. *Cognit. Sci.*, **13**, 145–182.
- , N. de Leeuw, M. M. Chiu, and C. LaVancher, 1994: Eliciting self-explanations improves understanding. *Cognit. Sci.*, **18**, 439–477.
- de Lisi, R., and S. L. Golbeck, 1999: Implications of Piagetian theory for peer learning. *Cognitive Perspectives on Peer Learning*, A. M. O'Donnell and A. King, Eds., Lawrence Erlbaum, 3–38.
- Enos, M. D., M. T. Kehrhahn, and A. Bell, 2003: Informal learning and the transfer of learning: How managers develop proficiency. *Hum. Resour. Dev. Quart.*, **14**, 369–387.
- Greenwood, J., 2000: Critical thinking and nursing scripts: The case for the development of both. *J. Adv. Nurs.*, **31**, 428–436.
- Gunawardena, C. N., C. A. Lowe, and T. Anderson, 1997: Analysis of a global online debate and the development of an interaction analysis model for examining social construction of knowledge in computer conferencing. *J. Educ. Comput. Res.*, **17**, 395–429.
- HPRCC, 1994: *Proceedings of the User Workshop on Long-Lead Climate Forecast in the High Plains Region*. Lincoln, NE, High Plains Regional Climate Center, University of Nebraska at Lincoln, 40 pp.
- Hu, Q., and Coauthors, 2006: Understanding farmers' forecast use from their beliefs, values, social norms, and perceived obstacles. *J. Appl. Meteor. Climatol.*, **45**, 1190–1201.
- Jagtap, S. S., J. W. Jones, P. E. Hildebrand, D. Letson, J. J. O'Brien, G. Podestá, D. Zierden, and F. Zazueta, 2002: Responding to stakeholder's demands for climate information: From research to applications in Florida. *Agric. Syst.*, **74**, 415–430.
- Kreber, C., 2001: Learning experientially through case studies? A conceptual analysis. *Teach. Higher Educ.*, **6**, 217–228.
- McCarthy, M. T., J. M. Webb, and T. E. Hancock, 1995: Form of feedback effects on verb learning and near-transfer tasks by sixth graders. *Contemp. Educ. Psychol.*, **20**, 140–150.
- McCown, R. L., 2005: New thinking about farmer decision makers. *The Farmer's Decision: Balancing Economic Agriculture Production with Environmental Quality*, J. L. Hatfield, Ed., Soil and Water Conservation Society, 11–44.
- McDade, S. A., 1995: Case study pedagogy to advance critical thinking. *Teach. Psychol.*, **22**, 9–10.
- Merseth, K., 1991: The early history of case-based instruction: Insights for teacher education today. *J. Teach. Educ.*, **42**, 243–249.
- Millner, A., 2008: Getting the most out of ensemble forecasts: A valuation model based on user-forecast interactions. *J. Appl. Meteor. Climatol.*, **47**, 2561–2571.
- Newman, D. R., C. Johnson, B. Webb, and C. Cochrane, 1997: Evaluating the quality of learning in computer supported cooperative learning. *J. Amer. Soc. Inf. Sci.*, **48**, 484–495.
- Nickerson, R. S., 1998: Confirmation bias: A ubiquitous phenomenon in many guises. *Rev. Gen. Psychol.*, **2**, 175–220.
- Pea, R. D., 2004: The social and technological dimensions of scaffolding and related theoretical concepts for learning, education, and human activity. *J. Learn. Sci.*, **13**, 423–451.
- Pedersen, S., and M. Liu, 2002: The effects of modeling expert cognitive strategies during problem-based learning. *J. Educ. Comput. Res.*, **26**, 353–380.
- Piaget, J., 1932: *The Moral Judgment of the Child*. Harcourt, Brace, and World, 418 pp.
- Putnam, R. T., and H. Borko, 2000: What do new views of knowledge and thinking have to say about research on teacher learning? *Educ. Res.*, **29**, 4–15.
- Rayner, S., D. Lach, and H. Ingram, 2005: Weather forecasts are for wimps: Why water resource managers do not use climate forecasts. *Climatic Change*, **69**, 197–227.
- Renkl, A., 2002: Worked-out examples: Instructional explanations support learning by self-explanations. *Learn. Instr.*, **12**, 529–556.
- Roscoe, R. D., and M. T. H. Chi, 2008: Tutor learning: The role of explaining and responding to questions. *Instruct. Sci.*, **36**, 321–350.
- Roy, M., and M. T. H. Chi, 2005: The self-explanation principle. *The Cambridge Handbook of Multimedia Learning*, R. E. Mayer, Ed., Cambridge University Press, 271–286.
- Schunk, D. H., and J. M. Rice, 1993: Strategy fading and progress feedback: Effects on self-efficacy and comprehension among students receiving remedial reading services. *J. Spec. Educ.*, **27**, 257–276.
- Slovic, P., 1987: Perception of risk. *Science*, **236**, 280–285.
- Stolovitch, H. D., and A. Yapi, 1997: Use of case study method to increase near and far transfer of learning. *Perform. Improv. Quart.*, **10**, 64–82.
- Thomas, M. J. W., 2002: Learning within incoherent structures: The space of online discussion forums. *J. Comput. Assist. Learn.*, **18**, 351–366.
- Vogel, C., and K. O'Brien, 2006: Who can eat information? Examining the effectiveness of season climate forecasts and regional climate-risk management strategies. *Climate Res.*, **33**, 111–112.
- Vygotsky, L. S., 1978: *Mind in Society: The Development of Higher Psychological Processes*. Harvard University Press, 159 pp.