Effects of Traditional Classroom and Distance Continuing Education: A Theory-Driven Evaluation of a Vaccine-Preventable Diseases Course

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A B S T R A C T

Objectives. This study evaluated the effects of a major federal immunization continuing education course, delivered in both traditional classroom and satellite broadcast versions, on public health professionals' knowledge, agreement, self-efficacy, and adherence in practice to recommendations.

Methods. The study used a comparative time series design to determine whether the course influenced participants' knowledge, agreement, self-efficacy, and adherence in practice to general and polio-specific recommendations as measured immediately and 3 months after the course. It also compared the effects of the classroom and satellite broadcast versions and used path analysis to show how the outcomes were related to one another.

Results. Both versions significantly improved knowledge, agreement, self-efficacy, and adherence. Knowledge and agreement were significant predictors of self-efficacy, which directly predicted adherence. Vaccine availability and supportive clinic policies were also important adherence predictors.

Conclusions. A well-designed training update can change provider knowledge, agreement, self-efficacy, and adherence. Traditional classroom and distance training can have comparable effects. The findings support incorporation of distance learning in national public health training, if the distance learning is used wisely in relation to training needs, goals, and practice contexts. (*Am J Public Health.* 2000;90:1218–1224)

Recent literature has recommended the use of technologies such as the Internet and satellite broadcasts to provide continuing education to the public health workforce.[1–7] Although many studies have shown that continuing education can be effective,[8] few have examined the effect of continuing education on public health professionals. Very few studies have examined the effects of the Internet or satellite training on public health practice[9] or compared the effects of such training with those of traditional "face-to-face" or "classroom" training. This study examined a continuing education program's effects on practice and other outcomes, compared the effects of satellite broadcast and classroom versions of that program, and examined the mechanism by which both courses influence practice.

The National Immunization Program's Vaccine-Preventable Diseases Course

A prominent recent public health training course has been "The Epidemiology and Prevention of Vaccine-Preventable Diseases" (henceforth, "the course"), offered by the National Immunization Program of the Centers for Disease Control and Prevention (CDC).[3] This course was originally taught in classrooms, but the National Immunization Program added a satellite broadcast (henceforth, "broadcast") version in 1995, which has enrolled more than 100 000 professionals. The classroom and broadcast courses have identical major faculty, content, teaching methods (slide-lecture, video, cases, question and answer), and materials (guides, textbook). The course's main objective is to increase professionals' adherence in practice to recommendations. The course teaches basic principles, the general recommendations on immunization of the Advisory Committee on Immunization Practices,[10] and the Advisory Committee on Immunization Practices childhood immunization schedule.

The 2.5-day classroom course is offered 10 to 20 times annually, with 50 to 250 participants each time. The broadcast course consists of four 3.5-hour telecasts on consecutive Thursday afternoons from the CDC to hundreds of downlink sites at colleges, health care facilities, and other locations. An average of approximately 5000 learners attend each broadcast course. Both courses total 14 hours of core instructional time.

This study focused on the new "sequential" polio schedule.[11] Polio prophylaxis requires 4 childhood vaccinations. Until September 1996, policy recommended that all 4 doses be delivered orally in most circumstances. After that date, policy recommended that 2 doses of inactivated polio vaccine be given by injection, followed by 2 doses of oral polio vaccine. This study focused on the polio schedule because the schedule's release created an opportunity to study the course's effectiveness in increasing adherence to a specific new recommendation.

This study also examined the course's influence on adherence to Advisory Committee on Immunization Practices general recommendations.[10] These recommendations encourage administering vaccines simultaneously during a single visit and giving vaccines to children with low-grade fevers and varied minor

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ailments, which many professionals falsely believe are contraindications. Both procedures are safe and prevent "missed opportunities" to vaccinate children.[12]

We also measured the courses' influence on participants' knowledge, agreement (with beliefs about vaccination taught in the course), and self-efficacy (specific confidence related to choosing and recommending vaccines) and the effect on adherence of several variables in the practice setting. We used the behavioral science theories described later in this article to construct a model with these outcomes to open up the "black box" between the course and practice—that is, to yield causal explanation in addition to showing a causal connection between the course and practice.[13,14] Such studies can more completely describe and explain program effects and contribute more to the development of theory about continuing education effectiveness than can studies measuring single outcomes. The continuing education literature is replete with studies showing causal connections between courses and practice but is bereft of studies showing how those practice changes were produced.[8]

This study examined the following research questions:

1. Do the classroom and broadcast courses significantly increase participants' knowledge, agreement, self-efficacy, and adherence in practice to recommendations?
2. Is there a statistically significant difference between the classroom and broadcast courses' effects on knowledge, agreement, self-efficacy, and adherence?
3. What is the mechanism by which the course influences adherence to polio vaccination and general recommendations?

Methods

Theoretical Framework

The model used to examine the program's effects was rooted in several health behavior theories, including the health belief model,[15,16] social cognitive theory,[16–18] the transtheoretical model,[19,20] and the theory of reasoned action.[21] It postulated that training influences adherence by changing related knowledge, agreement, and self-efficacy. Adherence also requires skill and support from the policies, peers, and supervisors of the organization in which practice occurs. A vast experimental literature[8,22–27] also supported the model, and our extensive interviews with participants, their supervisors, and National Immunization Program personnel provided convergent validation of the model and the findings.[28–30]

Design

This study merged 2 research designs. The comparative time series design,[31] which is used to compare the effects of interventions over time, was used to test for a causal connection between the course and the knowledge, agreement, self-efficacy, and adherence of respondents. It also compared the classroom and broadcast courses' effects on these outcomes. Each of these outcomes was measured with written surveys given immediately before the course (survey 1 at observation 1), immediately after the course (survey 2 at observation 2), and by mail 3 months after the course (survey 3 at observation 3).

A longitudinal survey design[32] was then used to test our model for explaining *how* the course produced changes in practice. In this design, groups complete surveys that measure the levels of variables at several time points, and regression or path analysis is used to explain how the variables are related to one another over time. We used path analysis to examine how the changes in knowledge, agreement, and self-efficacy led to changes in adherence. Path analysis is an extension of regression analysis that examines the relations among variables in a theoretical model.[33]

In summary, the comparative time series design tested for a causal connection between the course and several outcomes and compared the effects of the 2 versions. The path analysis took the same data and explained how the course produced the changes in adherence.

Sample: Treatment Groups and Characteristics

Treatment group 1 (classroom) consisted of all participants in 2 courses held in California in April 1997, 1 course held in Indiana in April 1997, and 2 courses held in Texas in July/August 1997. Of the 470 participants who completed survey 1 (observation 1), 413 completed survey 2 (observation 2), and 238 returned survey 3 (observation 3). Because we examined changes over time, we included only data from the 196 participants who completed all 3 surveys, for a usable group 1 return rate of 42%. Participants were informed of their participation at all 3 time points. Those who did not return the first mailed survey were sent a second survey.

Treatment group 2 (broadcast) included all participants at several downlink locations in California and Texas during a June 1997 course. Of the 251 participants who completed survey 1, 116 completed all 3 surveys, for a usable group 2 return rate of 46%.

For the 2 groups combined, 312 participants returned all 3 surveys, for a usable return rate of 43%.

We pooled the classroom courses into a single group because each offering uses identical main instructors, content, and materials. We pooled the broadcast courses into a single group because they were included in the same series.

The majority of both groups were trained in nursing, had clinical or managerial duties, and worked for a state, city, or county public health agency (Table 1). The classroom course had a higher proportion of nurses and participants with clinical responsibilities than did the broadcast course. Of the classroom participants, 65% personally vaccinated children and 52% had personally vaccinated infants younger than 6 months in the month preceding the course. Smaller percentages of broadcast participants vaccinated children (35%) and infants (24%). These differences would not be expected to affect adherence findings, because only those participants who personally vaccinated children answered the adherence questions. Effects of these differences on other study outcomes are unknown, but systematic confounding seems unlikely.

No significant difference was found between the usable return rates for the classroom and broadcast courses ($\chi^2_1 = 1.12$, $P = .29$) overall or within California ($P = .96$) and Texas ($P = .21$). For each variable listed in Table 1, no significant difference was found between the return rates for the classroom and broadcast courses.

Measurements: The Surveys

We measured each outcome with a composite score from a set of questions designed to measure that outcome.[34] All variables, and the way they were operationalized, were rooted in behavioral theory and interviews. The instruments were pretested in several states and types of organizations.[35]

Knowledge (surveys 1, 2, and 3). Each participant's knowledge of the polio vaccination schedule was measured by totaling the correct responses to 5 multiple-choice questions, for a maximum score of 5. For example, one question asked, "Which of the following best describes the new schedule now recommended by the CDC for routine polio vaccination?"

Agreement (surveys 1, 2, and 3). Each participant's agreement score was computed by totaling how strongly she or he agreed with 8 statements about the polio schedule; a 5-point scale ranging from "strongly disagree" to "strongly agree" was used, for a maximum score of 40. For example, one question asked,

TABLE 1—Characteristics of Classroom and Broadcast Course Participants

	Classroom Course (n = 196), %	Broadcast Course (n = 116), %	P^a	Combined Courses (n = 312), %
Professional training			.007	
Nursing	72	55		66
Nurse practitioner/physician assistant	7	7		7
Doctor of medicine/doctor of osteopathy	4	7		5
Management	5	4		5
Other	12	27		17
Current work responsibilities			<.001	
Clinical	58	45		53
Management	20	15		18
Education/outreach	12	11		12
Infection control/epidemiology	6	10		7
Other	5	20		10
Employers			.089	
State/city/county public health agency	61	55		59
Federal public health agency	9	4		7
Public hospital	9	6		8
Private health care organization	16	25		19
School, college, or university	6	11		8
Vaccination responsibilities				
Vaccinate children younger than 18 y	65	35	.001	54
Vaccinate infants aged 6 mo	52	24	.012	40

[a]Probability that groups are the same on response options within this category, based on the Pearson χ^2 test.

"How would you rate your overall agreement or disagreement with the changes in the recommended polio schedule?" Other questions reflected beliefs taught in the course that were related to the health belief model,[15,16] including perceptions that the schedule's benefits outweigh any perceived increased risks.

Self-efficacy (surveys 1, 2, and 3). Self-efficacy refers to "people's belief in their capability to organize and execute the course of action required to deal with prospective situations."[36(p38)] Each participant's score was computed by totaling his or her responses to 2 questions. Each question used a 4-point scale ranging from "not at all confident" to "completely confident," for a maximum score of 8. The first asked how confident participants were that they could select and explain the proper polio recommendation to a parent (important exceptions to the new policy depend on child and family factors). The second asked how confident participants were that they could explain to a coworker the rationale for the polio schedule. Being able to confidently choose, explain, and justify the proper vaccine was the focus; actually giving the vaccine is not difficult.

Adherence to the general recommendations (surveys 1 and 3). Participants completed the 3 questions regarding simultaneous vaccination and false contraindications, each with a response range of 1 to 5, only if they personally vaccinated children. Having properly vaccinated 0% of the children within the last month was rated 1, and having properly vaccinated 76% to 100% of the children was rated 5, for a maximum score of 15.

Adherence to the polio recommendations (surveys 1 and 3). Participants answered the 4 polio adherence questions, each with a response range of 1 to 5, only if they had personally vaccinated children younger than 6 months within the month before completing the survey. Having properly vaccinated 0% of the children within the last month was rated 1, and having properly vaccinated 76% to 100% of the children was rated 5, for a maximum score of 20.

Setting factors (surveys 1 and 3). The model also analyzed the influence on adherence of 3 perceived setting factors, all measured by questions that used a 5-point scale ranging from "strongly disagree" to "strongly agree." Perceived organizational policy support for the polio schedule and inactivated polio vaccine availability were each measured by 1 question, both with a maximum score of 5 for "strongly agree." Organizational norm in favor of implementing the polio schedule was measured by a composite of 3 questions, with a maximum score of 15 for "strongly agree" for all 3 questions. These questions asked about the support of parents, supervisors, and coworkers, respectively.

One question on surveys 1 and 3 asked participants if they were aware that the CDC had begun recommending a new polio schedule.

Reliability tests (Cronbach α) were computed for each outcome at each time point (Table 2), indicating acceptable levels of reliability in virtually every case.[34]

Data Analysis

An α level of 0.05 was used for all statistical tests. For research question 1, paired-samples *t* tests were used to examine whether the mean composite scores for each outcome were significantly different between survey administrations at observation 1 and observation 2, observation 2 and observation 3, and observation 1 and observation 3.

For research question 2, we used SPSS[37] to conduct analysis of covariance to examine the net difference between the classroom and broadcast courses' effects on knowledge, agreement, self-efficacy, and adherence, while controlling for initial differences. Measures at observation 3 were treated as response variables, and the corresponding measures at observation 1 were used as covariates.

For research question 3, we used LISREL[38] to conduct path analysis, with all measurements taken from observation 3 and with additional measurements of prior practice taken from observation 1.

Results

Classroom Course Outcomes

Eighty-eight percent of the participants were aware of the new polio schedule when

TABLE 2—Variables, Items, Score Range, and Reliability Estimates for Surveys

	Item Number				Reliability Estimates (Cronbach α)		
	Survey 1	Survey 2	Survey 3	Score Range	Survey 1	Survey 2	Survey 3
Major profession	1	. . .	1	1–5	. . .	. . .	. . .
Current work	2	. . .	. . .	1–5	. . .	. . .	. . .
Type of employer	3	. . .	. . .	1–5	. . .	. . .	. . .
Awareness	4	. . .	. . .	1–2	. . .	. . .	. . .
Knowledge	5–9	1–5	2–6	0–5	0.7243	0.5888	0.5539
Agreement	10–17	6–13	7–14	8–40	0.7291	0.6099	0.6343
Self-efficacy	18–19	15–16	15–16	2–8	0.9535	0.9667	0.9458
Setting factors							
Organization's policy	20	. . .	17	. . .	. . .	. . .	. . .
Inactivated polio vaccine availability	21	. . .	18	. . .	. . .	. . .	. . .
Social norm	22–24	. . .	19–21	. . .	0.6985	. . .	0.7484
Vaccinate children?	25	17	22	1–2	. . .	. . .	. . .
General recommendations vaccination behavior	26–28	18–20	23–25	3–15	0.8046	0.9235	0.8536
Vaccinate infants?	29	21	26	1–2	. . .	. . .	. . .
Polio recommendations vaccination behavior	30–33	22–25	27–30	4–20	0.8886	0.8615	0.8532

TABLE 3—Effects of Classroom and Broadcast Courses on Participant Knowledge, Agreement, Self-Efficacy, and Adherence to Both the Polio Recommendations and the General Recommendations

		Classroom			Broadcast		
Outcome	Time	n	Mean (SD)	Significance of Comparison*	n	Mean (SD)	Significance of Comparison*
Knowledge of the polio schedule	Before	196	3.82[a] (1.40)	. . .	116	2.68[a] (1.61)	. . .
	After	196	4.48 (0.89)	1–2 = P < .001	116	4.19 (1.16)	1–2 = P < .001
	3-month follow-up	196	4.52 (0.85)	1–3 = P < .001; 2–3 = NS	116	4.24 (1.07)	1–3 = P < .001; 2–3 = NS
Agreement with the polio schedule	Before	196	33.80[b] (5.55)	. . .	115	32.37[b] (5.91)	. . .
	After	196	38.38 (2.27)	1–2 = P < .001	115	37.37 (3.33)	1–2 = P < .001
	3-month follow-up	196	37.36 (2.71)	1–3 = P < .001; 2–3 = P < .001	116	37.01 (3.60)	1–3 = P < .001; 2–3 = NS
Self-efficacy with respect to the polio schedule	Before	195	4.68[c] (2.09)	. . .	115	3.53[c] (1.99)	. . .
	After	194	6.93 (1.84)	1–2 = P < .001	115	6.55 (1.96)	1–2 = P < .001
	3-month follow-up	195	6.88 (1.64)	1–3 = P < .001; 2–3 = NS	116	6.39 (1.97)	1–3 = P < .001; 2–3 = NS
Adherence to the general recommendations	Before	107	11.50[d] (4.22)	. . .	32	9.50[d] (4.49)	. . .
	After	. . .	. . .	. . .	. . .	. . .	. . .
	3-month follow-up	107	12.38 (3.63)	1–3 = P < .05	32	11.84 (4.31)	1–3 = P < .05
Adherence to the polio schedule	Before	91	9.30[e] (5.71)	. . .	24	11.96[e] (5.71)	. . .
	After	. . .	. . .	. . .	. . .	. . .	. . .
	3-month follow-up	91	16.25 (4.90)	1–3 = P < .001	24	14.42 (5.44)	1–3 = P = .084

[a]Maximum score is 5.
[b]Maximum score is 40.
[c]Maximum score is 8.
[d]Maximum score is 15.
[e]Maximum score is 20.
*P values given are for the paired-samples t test.

they arrived at the course. At the end of the classroom course, participants' knowledge of, agreement with, and self-efficacy with regard to the polio schedule were significantly increased over their levels before the course (P<.001) (Table 3). The significant increases in knowledge, agreement, and self-efficacy were maintained 3 months later (P<.001). Agreement with the polio schedule declined between the end of the course and the 3-month follow-up (P<.001) but was still significantly greater than it had been before the course (P<.001). Between the start of the classroom course and the 3-month follow-up, participants significantly increased their adherence to the general recommendations (P<.05) and to the polio schedule (P<.001).

Broadcast Course Outcomes

Seventy percent of the participants were aware of the new polio schedule when they arrived at the course. For the classroom and broadcast courses combined, 81% were aware of the new polio schedule when they arrived at the course. At the end of the broadcast course, participants' knowledge of, agreement with, and self-efficacy with regard to the polio schedule were significantly increased over their levels before the course (P<.001) (Table 3). These significant increases were maintained 3 months after the course.

Between the start of the broadcast course and the 3-month follow-up, participants significantly increased their adherence to the general recommendations (P<.05). They also in-

creased their adherence to the polio recommendations, but this result did not reach statistical significance at the .05 level ($P=.084$).

Comparing the Effects of the Classroom and Broadcast Courses

No significant difference was found between the increases in knowledge and self-efficacy for participants in the classroom and broadcast courses, both immediately following and 3 months after the course. Participants' immediate postcourse increases in agreement with the polio schedule were significantly greater for the classroom course than for the broadcast course ($P=.006$). After 3 months, however, there was no significant difference between classroom and broadcast course participants' agreement with the polio schedule, reflecting a decline in classroom participants' agreement over time. Both classroom and broadcast agreement scores, however, were significantly greater immediately after the course, and at the 3-month follow-up, than before the course (Table 3).

At the 3-month follow-up, no significant difference was found between classroom and broadcast participants' increases in adherence to the general recommendations. Participants' increases in adherence to the polio schedule, however, were significantly greater for participants in the classroom course ($P=.022$) than for those in the broadcast course. As noted earlier in this article, the broadcast course produced an increase in adherence to the polio schedule, but this increase did not reach statistical significance (Table 3).

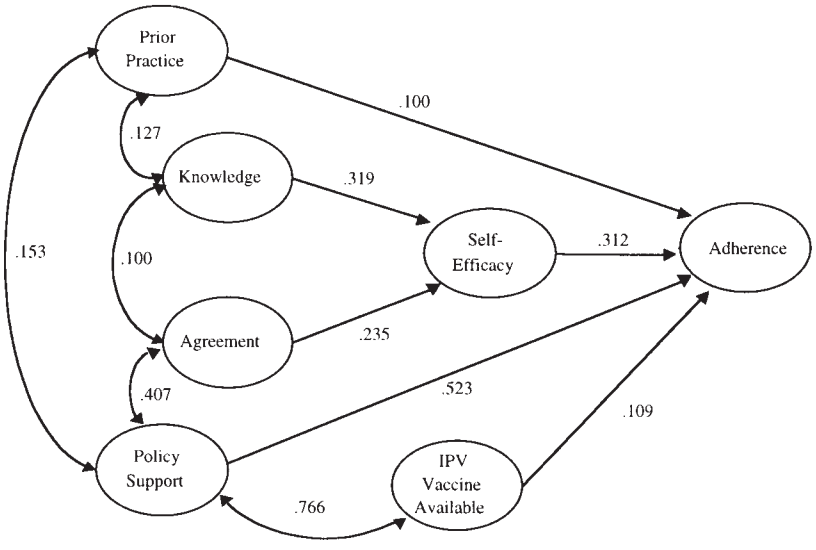
Explaining How the Course Affects Adherence

For the path analyses for adherence to the polio schedule (Figure 1) and general recommendations, participants in the classroom and broadcast courses were combined. A line with 1 arrow indicates the direct influence of 1 variable on another, and the statistic given is a standardized path coefficient (SPC), which can be viewed as a standardized regression coefficient for 1 variable in relation to another when the effects of all the other variables are partialed out. A curve with 2 arrows reflects correlation between the 2 linked variables, and the statistic is a correlation coefficient. All coefficients presented in Figure 1 are statistically significant ($P<.05$).

Prior practice significantly predicted adherence to the polio schedule (SPC=0.100). Self-efficacy had a strong direct influence on adherence (SPC=0.312), and knowledge (SPC=0.319) and agreement (SPC=0.235), in turn, were significant predictors of self-efficacy. We theorize that the course improved self-efficacy partly through increasing participants' knowledge of and agreement with the schedule. Also, organizational policy in support of the polio schedule (SPC=0.523) strongly predicted adherence and was highly correlated with the availability of inactivated polio vaccine. Policy support was also strongly correlated with agreement, indicating that participants were more likely to agree with the course if their organizations had already adopted the new polio policy by the observation 3 time point. Vaccine availability was also a direct predictor of adherence.

These relationships were similar for the general recommendations, with the unsurprising exceptions that policy support in favor of the polio recommendations was a weaker predictor of adherence and that inactivated polio vaccine availability did not predict adherence to the general recommendations.

Organizational norm was not a significant predictor of any outcomes, nor was it significantly correlated with any other variables for polio or the general recommendations.



Note. All regression coefficients (→) and correlation coefficients (↔) are statistically significant ($P<.05$). IPV = inactivated polio vaccine.

FIGURE 1—Path analysis for adherence to polio schedule.

Discussion

Both the classroom and the broadcast courses significantly improved knowledge, agreement, and self-efficacy in relation to the new polio schedule. The classroom and broadcast courses had similar effects on adherence to the general recommendations, whereas the classroom course had a somewhat stronger influence on initial agreement with, and adherence to, the polio schedule.

Path analyses showed that knowledge and agreement were significant predictors of self-efficacy, which directly predicted adherence. Vaccine availability and supportive policies predicted adherence to the polio schedule, and supportive policies were correlated with both polio schedule agreement and vaccine availability.

Lack of a control group introduces threats to the internal validity of the study, but several arguments for the validity of the conclusions can be drawn. First, 81% of the participants were aware of a new polio schedule, but their polio-related knowledge, agreement, and self-efficacy were significantly higher immediately after the course. Second, participants may have changed during the study or soon thereafter without the course, but the general recommendations had been promulgated since 1994, and the course significantly increased adherence to them. Third, the model was based in behavioral theory and supported by extensive interviews with participants and their supervisors about education needs and course effects. Also, participants may have been more likely than nonparticipants to change because of their interest in or organizational support for sound practice. Yet, many participants did not attend voluntarily. Furthermore, our interviews indicated that in the absence of the course, many participants, regardless of motivation, would not have had access to credible explanations of new policy.

Another study limitation was small sample sizes. With slightly larger samples, the

broadcast course may have had a significant effect on adherence to the polio schedule at the .05 level, because it fell just short of that level.

The findings support the use of continuing education to foster implementation of practice guidelines and recommendations.[39,40] Publishing policies through scientific and professional channels increased awareness that a policy existed, but the course led to increases in knowledge, agreement, self-efficacy, and adherence.

The findings also support literature in continuing education[8,23,41,42] and immunization services[12,43–46] showing that programs are most likely to improve practice when they address not only providers' knowledge, beliefs, and skills but also characteristics of the practice setting, such as policies, procedures, and reminder systems. In this study, training outcomes (e.g., knowledge) and setting factors (i.e., supportive policies and vaccine availability) influenced adherence. Yet, much continuing education is still driven by the "update model," which assumes that knowledge gains are sufficient for practice improvement.[47]

The findings also support the use of distance learning for continuing education. The classroom and broadcast courses had similar effects on most outcomes. Moreover, the first broadcast course reached 10 640 participants, more than had been reached by the previous 10 years of classroom courses. An intervention that can raise the performance of such a large portion of the public health workforce in a few afternoons is worthy of attention in policy implementation.

No single study, however, is sufficient for broad generalizations.[13] The effectiveness of this course has been shaped by several factors. First, the course is taught by epidemiologists with years of experience teaching this material, who thoroughly understand the knowledge gaps and issues facing participants and who constantly modify the course to address emergent concerns. Second, the course was developed with the help of instructional and graphic designers, and the broadcast version uses the excellent services of the CDC. Third, although the recommendations are complex, administering vaccines is not. Teaching a skill that requires practice and feedback, such as addiction counseling, would require a more complex instructional model. Distance learning can be a primary component of such programs[7] but would need to be supplemented by local preceptors or other arrangements. Fourth, the reputation of the CDC and its instructors brings large audiences and lends credibility[48] to the content. Fifth, the National Immunization Program has a multifaceted policy implementation effort that, in concert with state and local agencies, produces many supports for the course's message, including vaccine distribution, software, and consultation.[43]

This study has shown that continuing education and distance learning can improve public health practice. More research is needed to document other ways to use these methods to address workforce educational needs. □

Contributors

K. E. Umble led the conceptualization of the design and interpretation of the results; he also wrote and edited most of the manuscript. R. M. Cervero participated in conceptualizing the design and interpreting the results and provided comments and guidance on drafts and decisions about presentation of results. B. Yang also participated in conceptualizing the design and interpreting the results; he also guided and performed all statistical analyses and made comments on drafts. W. L. Atkinson assisted in conceptualizing the study, reviewed instruments, and made comments on a draft.

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References

1. Hirano D, Dillenberg J. Transforming public health through distance learning. *J Public Health Manage Pract.* 1998;4:42–45.
2. Ibrahim MA, House RM, Levine RH. Educating the public health workforce for the 21st century. *Fam Community Health.* 1995;18:17–25.
3. Friede A, Blum HL, McDonald M. Public health informatics: how information-age technology can strengthen public health. *Annu Rev Public Health.* 1995;6:239–252.
4. Hinman AR. Distance learning and distance education: a personal perspective. *Am J Prev Med.* 1996;12:5–8.
5. Maibach E, Holtgrave DR. Advances in public health communication. *Annu Rev Public Health.* 1995;16:219–238.
6. *The Public Health Workforce: An Agenda for the 21st Century*. Washington, DC: Public Health Service; 1997.
7. Place J, Stephens T, O'Leary-Cunningham P. Delivering clinical-based training in a public health setting. In: Schreiber DA, Berge ZL, eds. *Distance Training: How Innovative Organizations Are Using Technology to Maximize Learning and Meet Business Objectives.* San Francisco, Calif: Jossey-Bass; 1998:223–235.
8. Umble KE, Cervero RM. Impact studies in continuing education for health professionals: a critique of the research syntheses. *Eval Health Prof.* 1996;19:148–174.
9. Maetz HM, Walton W, Smith M, et al. A satellite primer on tuberculosis: collaboration in distance education. *J Public Health Manage Pract.* 1998;4:46–55.
10. Centers for Disease Control and Prevention. General recommendations on immunization. *MMWR Morb Mortal Wkly Rep.* 1994;43(RR-1):1–38.
11. Centers for Disease Control and Prevention. Poliomyelitis prevention in the United States: introduction of a sequential vaccination schedule of inactivated poliovirus vaccine followed by oral poliovirus vaccine. *MMWR Morb Mortal Wkly Rep.* 1997;46(RR-1):1–25.
12. Szilagyi PG, Rodewald LE. Missed opportunities for immunizations: a review of the evidence. *J Public Health Manage Pract*. 1996;2:18–25.
13. Cook TD. A quasi-sampling theory of generalization in causal relationships. In: Sechrest LB, Scott AG, eds. *New Directions for Program Evaluation: Understanding Causes and Generalizing About Them.* San Francisco, Calif: Jossey-Bass; 1993:39–81.
14. Lipsey MW. Theory as method: small theories of treatments. In: Sechrest LB, Scott AG, eds. *New Directions for Program Evaluation: Understanding Causes and Generalizing About Them.* San Francisco, Calif: Jossey-Bass; 1993:5–38.
15. Janz NK, Becker MH. The health belief model: a decade later. *Health Educ Q*. 1984;11:1–47.
16. Rosenstock IM, Strecher VJ, Becker MH. Social learning theory and the health belief model. *Health Educ Q*. 1988;15:175–183.
17. de Vries H, Dijkstra M, Kuhlman P. Self-efficacy: the third factor besides attitude and subjective norm as a predictor of behavioural intentions. *Health Educ Res Theory Pract.* 1988;3:272–282.
18. Bandura A. *Self-Efficacy: The Exercise of Control*. New York, NY: WH Freeman; 1997.
19. Prochaska JO, DiClemente CC. Toward a comprehensive model of change. In: Miller WR, Heather N, eds. *Treating Addictive Behaviors*. New York, NY: Plenum; 1986:3–27.
20. Cohen SJ, Halvorson HW, Gosselink CA. Changing physician behavior to improve disease prevention. *Prev Med.* 1994;23:284–291.
21. Fishbein M, Ajzen I. *Belief, Attitude, Intention, and Behavior: An Introduction to Theory and Research*. Reading, Mass: Addison-Wesley; 1975.
22. Cervero RM. Continuing professional education and behavior change: a model for research and evaluation. *J Continuing Educ Nurs.* 1985;16:214–217.
23. Davis D, Thomson MA, Oxman AD, et al. Changing physician performance: a systematic review of the effect of continuing medical education strategies. *JAMA.* 1995;274:700–705.
24. Davis D, O'Brien MAT, Freemantle N, et al. Impact of formal continuing medical education: do conferences, workshops, rounds, and other traditional continuing education activities change physician behavior or health care outcomes? *JAMA.* 1999;282:867–874.
25. Green LW, Eriksen MP, Schor EL. Preventive practices by physicians: behavioral determinants and potential interventions. *Am J Prev Med.* 1988;4(suppl 4):101–107.
26. Morrow RW, Gooding AD, Clark C. Improving physicians' preventive health care behavior through peer review and financial incentives. *Arch Fam Med.* 1995;4:165–169.
27. Wergin JF, Mazmanian PE, Miller WW, et al. CME and change in practice: an alternative perspective. *J Continuing Educ Health Professions.* 1988;8:147–159.
28. *Phase II Evaluation Report for "The Epidemiol-*

ogy and Prevention of Vaccine-Preventable Diseases" Course. Atlanta, Ga: Centers for Disease Control and Prevention, National Immunization Program, Training and Education Branch; 1997.
29. Jick T. Mixing qualitative and quantitative methods: triangulation in action. *Adm Sci Q.* 1979;24: 602–611.
30. Greene J, Caracelli VJ, Graham WF. Toward a conceptual framework for mixed-method evaluation designs. *Educ Eval Policy Anal.* 1989;11: 255–274.
31. Mohr LB. *Impact Analysis for Program Evaluation.* Newbury Park, Calif: Sage Publications; 1992.
32. Pathman DE, Konrad TR, Freed GL, et al. The awareness-to-adherence model of the steps to clinical guideline compliance: the case of pediatric vaccine recommendations. *Med Care*. 1996; 34:873–889.
33. Hair JF, Anderson RE, Tatham RL, Black WC. *Multivariate Data Analysis*. Englewood Cliffs, NJ: Prentice-Hall; 1995.
34. Crocker L, Algina J. *Introduction to Classical and Modern Test Theory*. Fort Worth, Tex: Harcourt Brace Jovanovich College Publishers; 1986.
35. Converse JM, Presser S. *Survey Questions: Handcrafting the Standardized Questionnaire*. Newbury Park, Calif: Sage Publications; 1986.
36. Maibach E, Murphy DA. Self-efficacy in health promotion research and practice: conceptualization and measurement. *Health Educ Res Theory Pract.* 1995;10:37–50.
37. *SPSS User's Guide.* Chicago, Ill: SPSS Inc; 1988.
38. Joreskog KG, Sorbom D. *LISREL 8: User's Reference Guide*. Chicago, Ill: Scientific Software; 1993.
39. Dodek PM, Ottoson JM. Implementation link between clinical practice guidelines and continuing medical education. *J Continuing Educ Health Professions*. 1996;16:82–93.
40. Lomas J. Words without action? The production, dissemination, and impact of consensus recommendations. *Annu Rev Public Health*. 1991;12: 41–65.
41. Ottoson JM. Use of a conceptual framework to explore multiple influences on the application of learning following a continuing education program. *Can J Study Adult Educ*. 1995;9:1–18.
42. Ottoson JM. After the applause: exploring multiple influences on application following an adult education program. *Adult Educ Q*. 1997;47: 92–107.
43. Dini EF, Chaney M, Moolenaar RL, et al. Information as intervention: how Georgia used vaccination coverage data to double public sector vaccination coverage in seven years. *J Public Health Manage Pract*. 1996;2:45–49.
44. Hinman AR. What will it take to fully protect all American children with vaccines? *Am J Dis Child*. 1991;145:559–562.
45. Pierce C, Goldstein M, Suozzi K, et al. The impact of the standards of pediatric immunization practices on vaccination coverage levels. *JAMA*. 1996;276:626–630.
46. Mittman BS, Siu AL. Changing provider behavior: applying research on outcomes and effectiveness in health care. In: Shortell SM, Reinhardt UE, eds. *Improving Health Policy and Management*. Ann Arbor, Mich: Health Administration Press; 1992:195–226.
47. Nowlen PM. *A New Approach to Continuing Education for Business and the Professions: The Performance Model*. New York, NY: Macmillan; 1988.
48. Bettinghaus EP. *Persuasive Communication*. New York, NY: Holt, Rinehart, & Winston; 1980.