

Incorporating Experimental Research into the Instructional Development Process: *A Study of Psychomotor Practice in a Mediated Instructional Program*

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Abstract. Two versions of an instructional program designed to teach student nurses to perform intravenous infusions—a no-practice version and a more costly version involving individual practice with simulated arms—were developed using systematic development procedures. Effectiveness of the two versions was compared during field testing in two separate research studies, one conducted with students who had had prior training on a task (venipuncture) with several similarities to an infusion and one with students with no such prior training. In both studies, students using each version attained mean posttest scores above 80% in performing the infusion on a live subject and near 90% on the cognitive test. Surprisingly, there were no significant differences in effectiveness of the practice and no-practice versions in either study. The results indicate that experimental research incorporated into the development process can yield valuable information that enables program developers to make informed, data-based decisions about potential components of an instructional program.

The concepts of "research" and "development" are linked very closely in education, as in many other fields. Educators typically think of research and development in education either as a single field or as two closely related fields. While a close relationship between educational development and research certainly seems to be highly desirable, this relationship is seldom reflected in the actual process of developing an instructional program. Experimental research is not included as an explicit component of the development process in most models or systems of instructional development (e.g., Gagne and Briggs, 1979; Merrill and Tennyson, 1977; Popham and Baker, 1971), and there are few reports in the professional literature of experimental investigations conducted as a part of the development of a new instructional program. The low incidence of experimental research during development of instructional programs is somewhat surprising in view of the difficult decisions that instructional developers must often make about which of two or more instructional procedures or types of materials will work best in the program they are developing.

The present project involved development and field testing of an instructional program and incorporation of two experimental research studies as part of the development process. The instructional program was developed to teach student nurses the psychomotor skills of starting and discontinuing an intravenous infusion. The program was intended for regular use in a clinical laboratory setting as a part of an undergraduate nursing curriculum at the university level. The research studies were designed to determine which of two versions of the instructional program, one version of which was relatively costly, was most effective with students

from the population of intended users.

Administering an intravenous infusion involves both cognitive and motor aspects. Student nurses cannot be provided with repeated practice of the psychomotor skills on live subjects, of course, because it is impractical and unsafe. Realistic simulated practice can be provided using plastic injectable training arms which are very similar to real human arms, but the simulated arms are costly (about \$400 each) and additional learning and instructor time is required for the practice.

Because of the cost of the materials for providing psychomotor practice, the instructional designers made the decision to develop the program in two versions that could be compared experimentally during program tryouts. One version did not include psychomotor practice and was therefore relatively inexpensive. This version was designed to provide a considerable amount of exposure and focused training related to the criterion tasks and to be as effective as possible without providing psychomotor practice. It included two components, an instructional videotape and a live demonstration by the instructor, designed to portray realistically the step-by-step procedures for performing the criterion task. The psychomotor practice version of the program incorporated the entire no-practice version, plus individual practice of the intravenous infusion procedure with a simulated arm.

The effectiveness of the psychomotor practice and no-practice versions of the program were compared in two experimental research studies. The instructional materials and procedures for the two versions of the program had been formulated and developed using the instructional development procedures described by Sullivan (1971). The experimental investigations of the comparative effectiveness of the

two versions were incorporated into the field testing stage in the instructional development process. The field testing and associated research were conducted with student nurses representative of the population of intended users. Two criteria were used to assess student learning from the program: (1) performance on a paper-and-pencil test covering the procedures for an intravenous infusion and (2) performance in actually setting up and discontinuing an intravenous infusion on a live subject.

Instructional Program

The instructional program was designed to be administered by a qualified nursing instructor and to be used with professional nursing students as a part of their nursing curriculum. The instructional objectives for the program are that the student will successfully (1) start and (2) discontinue an intravenous infusion on a live subject.

The two versions of the program consisted of coordinated sets of materials and procedures developed expressly for the program and designed to produce student attainment of the instructional objectives. The components described below were identical for both versions.

- An Instructor's Guide, consisting of a brief description of the program and a step-by-step description of the procedures for administering it.
- A single-spaced, seven-page, 8 1/2 x 11" booklet consisting of a task-by-task description of the procedures for starting and discontinuing an intravenous infusion. Included at appropriate points throughout the text in the booklet were illustrations of specific steps in the procedures.
- A checklist summarizing in sequence each step for starting and discontinuing an infusion.
- A 10-minute color instructional videotape demonstrating the entire process of starting and discontinuing an infusion on a live subject. The infusion procedures demonstrated in the videotape were identical to those described in the booklet and summarized in the checklist.
- A live demonstration of the intravenous infusion process performed by the laboratory

instructor using a simulated arm.

Psychomotor practice in starting and discontinuing an infusion was included in the practice version of the program but not in the no-practice version. Each student in the practice version was given a simulated arm and a set of materials needed for starting and discontinuing an infusion (needle, tubing, fluid, tourniquet, tape, etc.). The student then individually practiced the intravenous infusion process, with each student using a simulated arm, for 15 minutes under instructor supervision in regular clinical groups of five to eight trainees. Except for this component in the practice version only, the two versions of the program were identical.

Study 1

Method

Subjects. The subjects were 40 upper division nursing students in the third semester of the undergraduate nursing program at Arizona State University. The subjects had no prior experience in starting or discontinuing intravenous infusions. They had been trained earlier in the semester in the skill of drawing blood through venipuncture, a skill which entails several procedures that are somewhat similar to the intravenous infusion procedures.

Instructional Materials. The instructional materials used in the study were the materials comprising the instructional program as described earlier—in the instructor's guide, the illustrated booklet describing the step-by-step procedures for an intravenous infusion, the checklist summarizing the procedures, and the 10-minute color videotape demonstrating the procedures for an infusion on a live subject. Also included for the groups in the psychomotor practice version was a simulated arm for each subject and the materials required for performing the infusion procedure.

Procedures. Six regular clinical groups composed of six to eight students each and comprising the total of 40 subjects were randomly assigned to the two versions of the program. The booklet and checklist on starting and discontinuing an infusion were distributed to all students at the regular class session preceding the laboratory session in which the remaining components of the program were administered. Students were instructed to study the booklet and checklist and to

learn their content prior to the laboratory session. Self-report data on a questionnaire administered at the end of the study indicated that students in each version of the program spent an average of 30-40 minutes studying these materials.

Each clinical group participated in its own regularly scheduled 90-minute laboratory session attended only by members of that group. At the beginning of the session, the videotape was shown to the group. Following the showing of the videotape, the laboratory instructor gave a demonstration of the infusion procedure using a simulated arm. The instruction was completed at this point for the no-practice groups. Each student in the psychomotor practice version was provided a simulated arm and materials at this point. The students in the practice version then received 15 minutes of practice with the simulated arms, supervised by the laboratory instructor.

The criterion measures described below were administered to each group immediately after the students had completed their version of the program—that is, to each no-practice group after the demonstration by the laboratory instructor and to each practice group after psychomotor practice with the simulated arms.

Criterion Measures. Two performance measures and an attitude inventory were employed in the study. These measures were administered after the instructional portion of the program in the order that they are described below.

The multiple-choice posttest was an 18-item test consisting of four-choice items assessing student knowledge related to the intravenous infusion procedure. The items, which were derived directly from information in the instructional booklet and videotape, covered the component skills for starting and discontinuing an infusion.

Student performance in actually setting up and discontinuing an infusion on a live subject was assessed by having each student perform the process one time from beginning to end on a laboratory partner. Each student was given the set of materials needed for starting and discontinuing an infusion (needle, fluid, tourniquet, etc.). The student's performance in starting and discontinuing the infusion was

evaluated individually by one of two evaluators, both of whom were experienced registered nurses. The two evaluators had been given detailed prior training, designed to yield consistency in the evaluation process and had been directed to intervene at any point in the process if the safety of the student on whom the procedure was being performed was in question. Using a checklist, the evaluator assigned a "yes

the item dealing with practice on a simulated arm. The wording of this item for the psychomotor practice groups was "Practice on a simulated arm increased my ability to perform the skill." For the no-practice groups, the words "would have" were inserted before "increased my ability..." Students also were asked on this questionnaire to report the amount of time they spent studying the instructional booklet.

percent) for subjects in the no-practice version. As was to be expected from the small observed between-group differences in mean scores, neither the difference between the two groups on the written posttest nor on the performance test was statistically significant.

Responses to the attitude questionnaire revealed highly positive attitudes toward the instruction from both groups. On the seven five-choice items that were identical for both groups, the mean scores were 4.64 (5.0 = most positive, i.e., subject marked "strongly agree" response choice for positive statements) for the practice group and 4.59 for the no-practice group. The one questionnaire item which was slightly different in wording for the two groups was the only item on which the response pattern differed appreciably between the groups. Twelve of the 20 subjects (60 percent) in the psychomotor practice group indicated strong agreement with the statement that "Practice on the simulated arm increased my ability to perform the skill," and 18 subjects in this group (90 percent) indicated either strong agreement or agreement. In the no-practice group, only four subjects (20 percent) indicated strong agreement that practice *would have* increased their ability to perform the skill, and only 11 (55 percent) indicated either strong agreement or agreement with the statement.

Study 2

It had been expected that the psychomotor practice version of the program would yield significantly better performance in Study 1 than the no-practice version, at least on the criterion task that required actual performance of an intravenous infusion on a live subject. One possible explanation for the lack of a significant difference between the practice and no-practice groups on this task was related to the prior experience of the subjects. Subjects had been trained earlier in the semester in drawing blood through venipuncture. It seemed plausible that there may have been a positive transfer effect from this procedure, which has several similarities to an intravenous infusion, that could have contributed to the performance of the no-practice group and offset the potential effects of psychomotor practice of the infusion process.

Table 1.
Mean Scores for Study 1 by Program Version

Criterion Measure	Program Version		Totals
	Psychomotor Practice	No Practice	
Written Posttest	16.6 (92%)	15.9 (88%)	16.25 (90%)
Performance Test	14.8 (82%)	15.0 (83%)	14.95 (83%)

NOTE: Maximum score on each measure is 18. N = 20 subjects in each program version.

or no" rating to each student's performance on each of 18 subskills comprising the entire procedure, resulting in a maximum score of 18 on performance of an actual infusion on a live subject. The evaluators were summoned to the laboratory after the instruction was completed so that they would not know which program version the students had completed. Interrater reliability for the two evaluators, computed on their independent step-by-step ratings of the performance of each individual in a clinical laboratory group not included in the study, was .88.

The attitude questionnaire administered at the conclusion of the laboratory session consisted of eight Likert-type items, rated on a five-choice scale from "strongly agree" to "strongly disagree," and three open-ended questions. The questionnaire was designed primarily to assess student attitudes toward each version of the instructional program. Items were identical on the questionnaire for each group with the intentional exception of

Data analysis. Mean scores were computed by program version on both the 18-item multiple-choice posttest and the performance of the infusion procedure on a live subject. The mean scores on the posttest and on the infusion procedure were analyzed independently for differences between the two groups using two separate analyses of variance.

Results

The mean scores by program version on the 18-item multiple-choice posttest and on performance of the intravenous infusion procedure are shown in Table 1. It can be seen from the table that there were only very minor differences in scores between the two groups. The mean scores on the written posttest were 16.6 items correct (92 percent) for students using the psychomotor practice version and 15.9 items correct (88 percent) for students in the no-practice version. The mean scores on the infusion performance test were 14.8 of 18 possible (82 percent) for the psychomotor practice subjects and 15.0 (83

Because of the unexpected results from Study 1 and the possibility that they were related to the subjects' prior experience with venipuncture, a second study was planned. This study was conducted with subjects who had no prior experience with venipuncture.

Method

Subjects for Study 2 were 34 nursing students in the same semester of the same program as the subjects in Study 1. The subjects in Study 2 followed a sequence through the curriculum that was slightly different from the sequence for the students in Study 1. Unlike the Study 1 subjects, they had had no prior experience with venipuncture or with any other procedures having similarities to intravenous infusion.

Due to the slightly smaller number of subjects in the Study 2 group (34 as compared to 40 in Study 1), the size of the regular clinical groups was five to seven students, instead of six to eight as in the earlier study. The number of subjects in each version of the program, was determined through random assignment of the regular clinical groups, with 15 in the psychomotor practice version and 19 in the no-practice version.

All procedures for Study 2 were identical to those in Study 1. The only differences in method between the two studies were the differences in prior experience and numbers of subjects described above. Self-report data on the questionnaire administered at the end of the study indicated that the students in

each version spent an average of 30-40 minutes studying the booklet and checklist prior to the laboratory sessions.

Results

The mean scores for Study 2 by program version on the 18-item posttest and on performance of the intravenous infusion procedure are shown in Table 2. Again, there was very little difference between the mean scores of subjects in the two program versions. On the written posttest, the mean scores of both groups were identical, 16.3 correct out of 18 (91 percent). The mean scores on the infusion performance test were 15.7 (87 percent) for the practice group and 14.6 (81 percent) for the no-practice group. This difference did not approach statistical significance.

Responses to the attitude questionnaire again were highly positive for both groups. The mean scores on the seven items that were identical for the two groups were 4.51 for the psychomotor practice group and 4.48 for the no-practice group. A similar pattern to Study 1 also occurred on the item dealing with practice on a simulated arm. Ten of the 13 subjects (77 percent) who completed this item from the psychomotor practice group indicated that they strongly agreed that practice with the simulated arm increased their ability to perform an infusion, whereas only four of the 19 students (21 percent) from the no-practice group strongly agreed that such practice would have increased their

ability.

Discussion

The present development and research effort was conducted to (1) develop an instructional program to teach professional nursing students to perform an intravenous infusion on a live subject and (2) to determine the relative effectiveness of two versions of the program that differed markedly in cost. The overall results served to validate the effectiveness of both versions of the instructional program, one with simulated psychomotor practice and one without, and to indicate that the two versions were about equally effective. Across the two studies conducted to compare the two versions of the instructional program, subjects under each version attained mean written posttest scores near 90 percent—91 percent for the practice groups and 89 percent for the no-practice groups. Mean scores across the two studies on performing an intravenous infusion on a live subject exceeded 80 percent for each of the two program versions—84 percent for students in the psychomotor practice groups and 82 percent for those in the no-practice groups. Students under each version indicated highly positive attitudes toward their particular instructional program.

The two experimental research studies incorporated into the field testing provided data that were very useful to the program developers and to instructors who planned to use the program. It had been expected that, at least for the criterion measure involving actual performance of an infusion, the version that included psychomotor practice with a simulated arm would be more effective than the no-practice version. Yet, scores on the performance measures were not significantly higher for students in the psychomotor practice version than for those in the no-practice version, even when students had had no prior clinical experience that was remotely similar to performing an intravenous infusion. Based on the results of the two studies, the no-practice version of the program was selected for use in the regular undergraduate nursing curriculum at Arizona State University. With a maximum clinical group size of eight students, the initial cost of materials for the psychomotor practice version is

Table 2.
Mean Scores for Study 2 by Program Version

Criterion Measure	Program Version		Totals
	Psychomotor Practice	No Practice	
Written Posttest	16.3 (91%)	16.3 (91%)	16.3 (91%)
Performance Test	15.7 (87%)	14.6 (81%)	15.15 (84%)

NOTE: Maximum score on each measure is 18. N = 15 in psychomotor practice version and 19 in no-practice version.

about \$3000 more than for the no-practice version. In the opinion of the program developers and clinical laboratory instructors, the slight, statistically unreliable, differences in performance associated with use of the psychomotor practice version did not justify the additional cost of using this more expensive version in the regular curriculum.

The negligible effect of the psychomotor practice is undoubtedly due in part to the general effectiveness of the non-practice components of the instructional program, as indicated by the performance scores of 89 percent on the written posttest and 82 percent on the actual infusion process for subjects in the no-practice version. The non-practice instructional components—the booklet, checklist, videotape, and live demonstration—were intentionally designed to provide highly relevant training, but no psychomotor practice on the criterion tasks. Apparently, practice in performing an intravenous infusion with a simulated arm, at least in the amount that could feasibly be provided in the present laboratory setting, is not enough to produce a significant improvement in cognitive knowledge or actual performance over these combined non-practice components. In view of this finding, students in the no-practice version

showed considerable insight when they generally did not indicate strong agreement with the statement on the attitude questionnaire that "Practice on a simulated arm would have increased my ability to perform the (intravenous infusion) skill."

The incorporation of experimental research into the development of an instructional program has generally been overlooked as a means for determining the final form of the program, both in models of instructional development and in the actual practice of development. Often, however, adequate information is not available to enable program developers to make decisions with confidence about which of two or more types of materials or sets of instructional procedures will be more effective, even in the case of material or activities that may vary considerably in cost and/or learner time required. As the present studies indicate, experimental comparisons of alternative materials and procedures during the development process can yield information that enables program developers and users to make informed, data-based decisions about the potential components of a program.

Two closely related recommendations, therefore, seem well justified. One is that, in the process of formulating and developing an in-

structional program, the developers should intentionally consider feasible variations in the program and the desirability of investigating the effects of the variations. The second is that an explicit reference to experimental research on the effects of alternative materials and procedures in an instructional program should be incorporated into models of instructional development as an optional step in the development process.

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