DOCUMENT RESUME

ED 314 025 IR 014 106

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TITLE Multiple Strand Sequencing Using the Elaboration Theory.
PUB DATE 87
NOTE 55p.
PUB TYPE Information Analyses (070) -- Reports - Research/Technical (143)

EDRS PRICE MF01/PC03 Plus Postage.
DESCRIPTORS Higher Education; *Instructional Design; Physical Therapy; Research Needs; *Sequential Approach; *Theory Practice Relationship
IDENTIFIERS *Elaboration Theory

ABSTRACT

This study examined the sequencing of instruction in a course in physical therapy. In the first phase, a procedural elaboration sequence was designed using the Simplifying Assumptions Method. In the second phase, a prescriptive-theoretical elaboration sequence independent of the procedural sequence was designed. A descriptive-theoretical elaboration consisting of principles which describe how the procedures work was designed in the third phase. In the final phase, the three sequences were integrated into a single course sequence. A prescriptive-to-descriptive-to-procedural sequence was selected as the logical order of presentation. Results show that it is possible to have parallel elaboration sequences of different content orientations (procedures and principles) integrated within a given course. Advantages of this design include: (1) students progress from simple to complex principles and procedures at the same time; (2) students develop both procedural and theoretical schemata while learning the interrelationships between the schemata; and (3) the designer is reminded of procedures or principles which might otherwise be missed. The phases and steps for designing related elaboration strands are outlined. The appendixes include an outline of the Simplifying Assumptions Method and the initial and revised blueprints for each of the three elaboration sequences. (13 references) (MES)

Multiple Strand Sequencing Using the Elaboration Theory

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ABSTRACT

While prior work on the elaboration theory has prescribed the sequencing of instruction based upon one type of content (procedural, conceptual or theoretical), complex subject matter often has two or even three different content orientations that are of equal importance in a course. Through analysis of a course which emphasizes the application of theory to practice in physical therapy treatment, we found that it is possible to develop an overall course sequence in which content of different orientations (procedural and theoretical) is presented in parallel elaboration sequences. The advantage to this type of sequencing is that all content (both procedural and theoretical) is presented in a simple to complex manner, thus facilitating the formation of stable schemata, and enhancing recall and transfer of learning.

There are many important concerns in creating good instruction, including decisions about what to teach and how to teach it. Regarding how to teach it, the major concerns include how to sequence the instruction, what instructional tactics (methods) to use, how to deliver the instruction (media utilization), and how to manage the learning process. This paper reports on a project to advance our understanding of how to sequence instruction.

Sequencing is an important aspect of instructional design for several reasons. First, the failure to master prerequisites can make it impossible for the learner to acquire a skill (Gagne, 1977) or understand something (Anderson, 1984; Ausubel, Novak & Hanesian, 1978). Hence, such prerequisites should be sequenced earlier than the knowledge for which it is prerequisite. Second, the sequence of instruction influences the formation of a schema, which can greatly facilitate the meaningful assimilation of new material (Anderson, 1984; Ausubel, et al., 1978; Rummelhart and Ortony, 1977), and thereby enhance both retention and transfer.

In spite of the importance of sequencing, relatively little knowledge has been developed about how to design the best possible sequence. Reigeluth has worked on integrating the knowledge generated to date, such as Gagne's (1977) hierarchical sequence, Bruner's (1960) spiral curriculum, and Ausubel's (1968) progressive differentiation, into a comprehensive set of prescriptions (Reigeluth & Stein, 1983). He has also worked on developing more operational guidelines on how to design each of the various sequences prescribed.

Reigeluth's work was borne out of a concern about the piecemeal "parts-to-whole" instructional sequences which resulted from applying Gagne's hierarchical sequence methodology. His goal was to develop more holistic sequences which foster greater understanding, motivation, and potential for learner control. With much initial guidance and inspiration from M. D. Merrill, he synthesized and extended earlier work into three different kinds of "elaboration" sequences. The conceptual elaboration sequence

(Reigeluth & Darwazeh, 1982) is based largely on Ausubel's work, and entails starting with broader, more inclusive concepts, followed by progressively more narrow and detailed kinds or parts of those concepts. The procedural elaboration sequence (Reigeluth & Rodgers, 1980) is based largely on the work of Scandura (1973) and P. Merrill (1978), and entails starting with a complete but simple version of the terminal task (similar to their notion of "shortest path" through the procedure) and progressing to ever more complex versions of the task. The theoretical elaboration sequence (Reigeluth, 1987) is based largely on Bruner's work, and entails starting with the simplest, most basic and intuitive principles in a subject area, followed by progressively more complex, narrow, and specific principles. In each of these three sequences, supporting content is "plugged in" wherever appropriate in the overall elaboration sequence.

The Elaboration Theory has always prescribed that just one type of content (concepts, procedures, or principles) should form the basis for the elaboration sequence in any given course (although other types of content are then included wherever appropriate within that sequence). However, two types of content are often of equivalent importance in a course, such as a course which focuses on both theory and practice. This type of course may have a procedural emphasis but also require the student to learn a considerable number of principles to gain an understanding of the procedure. The purpose of this project was to investigate whether or not it was possible and might even be more beneficial to simultaneously elaborate two types of content in a given course.

METHODOLOGY

To investigate this question, we decided to design elaboration sequences for each of two content orientations in a specific course, and then determine whether the sequences were compatible and could be combined. If so, we will then investigate the effectiveness of this "combination" sequence in a follow-up project. In most instances the design of elaboration sequences is performed through the joint effort of a subject-matter expert (SME) and an instructional designer. Due to funding constraints, however, the designer served as SME in this project.

We selected a course in a physical therapy educational program for two reasons. First, the course leant itself well to two different orientations. The content was largely procedural in nature, but with heavy emphasis on the scientific basis (theory) of procedure application. Second, one of the authors was currently teaching the course and was therefore able to serve the role of both designer and SME. The primary goal of the course is to enable the learners to select and use physical agents (heat, cold, electrical stimulation and light) in the management of pain.

This project progressed through four phases. Phases I through III involved designing elaboration sequences for the different content orientations, while Phase IV consisted of integrating the three sequences.

Phase I: Design a Procedural Elaboration

Since the predominant course content was procedural in nature, the first phase of the project was to design a procedural elaboration sequence. Reigeluth and Rodgers (1980) recommend use of "simplifying assumptions" for procedural elaborations. This technique allows one to identify progressively more difficult procedures (or paths of procedures) and sequence them in a simple-to-complex manner. To identify the procedural epitome, the SME is first asked to identify the simplest performance of the procedure he or she ever did, and to list the steps required for correct performance. Next, all the conditions which make this simplest case different from more complex cases are identified. These conditions are the simplifying assumptions.

After the steps comprising the epitome are listed and all simplifying assumptions are identified, the next more complex elaboration is identified for the second lesson in the elaboration sequence. To do this, the SME (subject-matter expert) is asked to identify the simplifying assumption that eliminated the most important or representative steps that are missing from the epitome. This assumption is then "relaxed," and the additional steps of the procedure are identified for the second lesson. Subsequent elaborations are constructed in the same manner until all steps of the procedure are included on a "blueprint" or outline of the course.

As the sequence is created, the necessary supporting content is noted on the blueprint to ensure that this information is included in the final sequence. See Appendix A for a more detailed description of the Simplifying Assumptions Method. Note that the procedures described in Appendix A utilize a 10-hour guideline for the amount of content to be included in any lesson (e.g. see step 1.1.5). For this project no time guidelines were used when designing the lesson blueprints because in the final sequence theoretical and procedural lessons would be combined.

The content selected for this project includes a relatively large number of procedures which are loosely interrelated; each procedure taught precludes the use of other procedures so that even in the most complex task the largest number of new steps taught in a single lesson is eighteen. The procedural epitome was selected by identifying the task that is the easiest and most frequently used by physical therapists and highly representative of their job of managing pain: application of hydrocollator packs (hot packs). The steps for applying hot packs were identified, and then all of the conditions that would lead one to use hot packs rather than another physical agent were identified. For example, if a patient had pain in the joints of the hand, hot packs would not be a practical treatment choice. On the other hand, hot packs are a good treatment for large surface areas. Therefore, one simplifying assumption in the epitome is that a patient has pain over a broad, proximal area of the body. Other assumptions identified for the procedural epitome included the lack of equipment for application of another type of physical agent (e.g. no fluidotherapy unit available), and certain medical complications, such as previous surgeries which preclude the use of other physical agents.

Assumptions, such as restricting the area of the body with pain or the presence of medical complications, were relaxed gradually to allow students to learn those procedures that are both easiest and most commonly used before the more complex or less frequently used procedures. Those assumptions which omitted the easiest and most frequently performed procedures were identified and relaxed first. For example, physical therapists frequently treat patients who have pain in areas of the body that are not proximal and not broad. By relaxing this assumption, the steps involved in the use of paraffin, a relatively simple procedure, could be taught immediately following the epitome.

For each subsequent elaboration the same procedure was used, i.e. the next most simple and frequently used procedure was identified, and the assumption which precluded the use of that procedure was relaxed. In some instances relaxing a simplifying assumption led to several new physical agents being appropriate, or allowed too large a number of steps to be taught in a single lesson. In such cases, additional simplifying assumptions were added as the initial assumption was relaxed. This allowed for a manageable amount of new material to be presented in each lesson. The procedural elaboration sequence resulted in a total of 12 lessons, each presenting a different physical agent. The initial procedural blueprint is shown in Appendix B.

Phase II: Theoretical Elaboration

The second phase of the project was to design a theoretical elaboration sequence independently of the procedural sequence. Reigeluth (1987) recommends three methods for designing a theoretical elaboration sequence. One is to identify the order in which the principles were discovered in the discipline. The simplest, most intuitive, most fundamental and broadly applicable ones were generally discovered first. Another is to ask your SME, "If you only had one hour to teach your students to apply a principle or two, which one(s) would you pick?" and "Which one(s) would you pick next?" Again, the simplest, most fundamental and broadly applicable one(s) will generally be picked first. The third method is to use a variation of the Simplifying Assumptions Method to restrict the complexity of the problem domain. Then you analyze the simplified problem domain to identify all principles which apply to it. Principles for subsequent elaborations are identified by relaxing the simplifying assumptions one at a time in a manner similar to that used for the procedural elaboration sequence.

Since the focus of the course was the on the use of physical agents in the management of pain, principles of pain evaluation and the physiological mechanisms for pain control were identified. These principles were then sequenced by selecting those principles which were the most fundamental and essential for instruction, followed by progressively more complex and less intuitive principles. The theoretical elaboration blueprint designed for this portion of the instruction is found in Appendix C.

Note that the epitome itemizes characteristics which influence a person's perception of pain. Lesson 2 expands on the first component of the epitome by detailing specific aspects of pain perception that should be evaluated in order to determine the level and type of pain that a given patient experiences. Additional principles introduced at this level of complexity include the body's physiological mechanisms for controlling pain that may be activated through use of the procedures being taught (Lesson 4, Appendix C). Levels two and three of elaboration add further detail to include progressively more complex mechanisms of pain control.

The final step in the development of this sequence was to review the procedural elaboration blueprint to determine whether any additional principles needed to be included. At this point it was noted that additional theoretical content needed to be presented but did not fit well into the first theoretical sequence. Analysis of the work revealed that the first theoretical elaboration was essentially prescriptive in nature. That is, it presented rules to guide students toward selection of certain steps of the procedure. The additional theoretical content deemed necessary for inclusion in the course was found to be descriptive. These principles, which described how the procedures worked, were used to create a third elaboration sequence independent of the first two sequences.

Phase III: Descriptive Theoretical Elaboration

To design the descriptive theoretical elaboration, the previously designed sequences (procedural and prescriptive-theoretical) were set aside, and principles which described how the procedures worked were listed. These principles were then organized into an elaboration sequence by identifying those principles that were determined to be the most intuitive and fundamental to the course content by identifying which principles would be taught if only one hour of instruction was allowed, then one more hour, etc. Principles regarding the physiological effects of heat were selected to be sequenced first, since most people have had experience with the soothing effects of warmth. Thus, the epitome includes principles related to how heat causes the soothing sensation (see Appendix D, Lesson 1).

Subsequent lessons expand on the principles presented in the epitome by describing in more detail the physics of heat transfer through conduction and radiation of energy. These lessons were again sequenced by the complexity of the principles presented, and the degree to which the principles were observable or intuitive. For example, conduction of energy was sequenced before radiation of energy because conduction was deemed both easier to understand than radiation and more familiar to the learner. Additionally, principles which govern the intensity of radiant energy are more complex than those principles which govern the intensity of conducted energy. Second-level elaborations deal with increasingly complex principles which relate to previously presented material. In Lesson 4, for example, basic principles of radiant energy emitted from hot sources are presented, while Lesson 7 is concerned with radiant energy from a more complex electrical source.

At this point the principles in the first theoretical sequence were reworded to reflect their prescriptive nature. Prescriptive principles typically take the format of "To (create some change) do (describe the action required)." Descriptive principles simply describe cause-and-effect relationships. For example, in the original theoretical blueprint the following principle was stated in descriptive terminology: "Physical agents stimulate non-nociceptive fibers to activate presynaptic inhibition at the dorsal horn, resulting in immediate, but short-lasting relief of pain." The wording of this same cause-and-effect relationship was changed to: "To achieve immediate but short-lasting relief of pain, apply physical agents which stimulate non-nociceptive sensory fibers to activate presynaptic inhibition at the dorsal horn." This change in wording reflects the prescriptive nature of the principle without altering its meaning. Other changes in the prescriptive blueprint included breaking the lesson content down into smaller units to allow greater ease of instruction.

As a final step in this phase of the project, textbooks and other resources were consulted to ensure that all of the important principles which required instruction were included in the elaboration blueprint. The resulting descriptive theoretical blueprint is found in Appendix D.

Phase IV: Integration of Sequences

Upon completion of the three sequences (procedural, prescriptive-theoretical, and descriptive-theoretical) the blueprints were laid side by side to determine whether they were compatible enough to be integrated into a single course sequence. Upon examination of the three blueprints, additional procedures which were missed during the development of the procedural sequence were identified and added to the procedural blueprint. Several related principles were also identified and inserted into the two theoretical-elaboration sequences.

The three sequences which were initially developed for the course are shown in Appendices B, C and D. When laid side by side, we were amazed to find significant parallels in content among the three sequences. However, to attain a more precise parallel it was necessary to reorder some of the lessons within a given level of elaboration. For example, in the initial procedural blueprint the procedure for use of infrared heating lamps was sequenced before use of cryotherapy, with both procedures being Level-1 elaborations. In the final procedural blueprint, cryotherapy was sequenced before infrared to allow greater parallel to the theoretical blueprints. This change in the procedural blueprint did not affect the elaboration since the lessons that were interchanged were on the same level of elaboration (level of complexity). The final sequences are shown in Appendices E, F and G.

Since it was found that the three elaboration strands (procedures, prescriptive principles, and descriptive principles) were parallel and that all could be taught simultaneously, two questions arose regarding the within-lesson sequencing of the course. The first question concerned the order in which related content from the strands should be introduced to the learner. The second question regarded whether the three types of content should be integrated (i.e. whether related prescriptive, descriptive and procedural content should be combined into one lesson), or "collated" (e.g. all of the content of one strand's lesson 1 should be followed by all of the content from the next strands' lesson 1, and so forth).

A prescriptive-to-descriptive-to-procedure sequence was selected as being the most logical order of presentation because the learner must first learn which procedures to perform (prescriptive), understand why those procedures are appropriate (descriptive), and then learn to perform them (procedure). This format of instruction follows the Elaboration Theory's guidelines for within-lesson sequencing, which state that principles should be taught before procedures, and learning prerequisites should be taught before the content for which they are prerequisite (Reigeluth, 1987) .

The final course sequence is shown in Figuro 1. Note that the theoretical and procedural lessons do not match up on a one-to-one basis. In some instances there is no new theoretical information that must be taught, and the first lesson includes two segments from the prescriptive theoretical sequence. Figure 2 shows the interrelationships between the three types of content for a single lesson.

In deciding between collating and integrating the lessons, the collated approach was selected as being more feasible for this content. In a course such as the one used for this project, principles are typically taught in a classroom setting and procedures are taught in a laboratory setting. Since the procedures to be taught involve physical manipulation of equipment, it seems reasonable to teach the principles related to how the procedure works before actually beginning to teach the procedure itself. This allows a greater fluidity in the performance of the procedure, and provides an additional opportunity to review principles as the procedure is taught.

For example, in Procedure Lesson 7 (shown in Figure 2) students learn to position patients for treatment and to adjust an infrared heating lamp to provide the correct intensity of heat to the patient. This requires an understanding of the Cosine Law and the Inverse Square Law. If the contents were to be integrated, students would learn and practice the Cosine Law to ensure that they understood the principle, then move to a laboratory setting to learn the procedure and practice positioning a "patient". Then students would be presented with the Inverse Square Law, practice its theoretical application (perhaps by performing numeric. calculations on paper), then return to the laboratory to practice adjusting the equipment over the patient.

If the contents were collated, students would be presented with the Cosine Law and practice its theoretical application to ensure mastery of the principle. In the same session they would learn and practice using the Inverse Square Law. Following presentation and practice of all the related principles, students would then move on to learning the procedure in a laboratory setting and, at the appropriate steps, be reminded of the principles.

CONCLUSIONS

The results of this project show that it is possible to have parallel elaboration sequences of different content orientations integrated within a given course. At the outset of this project the authors were uncertain whether it would be possible to develop parallel elaboration sequences for different content orientations. It was surprising to find how closely the sequences did parallel each other, and how little restructuring of the material was necessary to achieve a good fit. Furthermore, there appear to be several important advantages to designing parallel elaboration strands.

When multiple strands of content are fully analyzed, the elaborative relationships for each strand are identified. Simultaneous elaboration of two or more strands ensures that no content is presented in a non-elaborative sequence. Thus, each of the content strands presents increasingly complex content. This allows the learner to progress from simple to complex principles at the same time that he or she is progressing from simple to complex procedures (or concepts).

Instruction presented as elaborations of multiple strands of content should also enhance the formation and integration of multiple schemata. That is, students develop both a procedural schema and a theoretical schema for the same content area, while learning the interrelationships between the two schemata. The formation of these schemata enhances the learning of other new procedures and principles, and facilitates their retention and recall. Although the content used for this project focused on procedures and principles, it is conceivable that similar results may be obtained with conceptual content.

An additional advantage of sequencing courses in this manner is that, as secondary blueprints are developed, material that was missed when the first elaboration sequence was created can be identified and included in the final instructional blueprint. In this project the process of developing theoretical elaborations reminded the instructional designer/SME of other procedures that needed to be included in the instruction. Likewise, referring back to the previously developed procedural blueprint served to remind the designer of additional principles that were necessary to support the procedures.

The following phases and steps are recommended for designing related elaboration strands using the elaboration theory:

Phase One: Design the initial elaboration sequence.

Determine the dominant content orientation (theoretical, conceptual, or procedural) of the course to be taught.

Design an elaboration sequence based upon the dominant content orientation.

Use textbooks and/or other references to ensure that all important orientation content (procedures, principles, or concepts) is included in the initial elaboration sequence.

Include on the sequence blueprint all of the important supporting content.

Phase Two: Design the secondary elaboration sequence.

Set the first blueprint aside, and choose the next most important content orientation.

Design an elaboration sequence based upon this secondary content.

Again, use textbooks and other references to ensure that all of the important orientation content is included in the secondary content blueprint.

After the second blueprint is completed, refer back to the initial blueprint. Check to ensure that no important content has been omitted from either blueprint.

If all content which needs to be included in the instruction is represented on the blueprints, proceed to phase four. If additional content needs to be included, determine whether it can be integrated into the previously designed blueprints, or whether it represents an additional type of content. If the content can be integrated into an existing blueprint, do so, and proceed to phase four. If the content requires a separate elaboration sequence, proceed to phase three.

Phase Three: Design of the tertiary elaboration sequence.

If the additional content is of a different content orientation, design a separate (tertiary) elaboration sequence.

After completing the tertiary blueprint, compare it to the other blueprints. Check for comprehensiveness of the content. If you find that additional content needs to be presented, add it to the appropriate blueprint.

Phase Four: Integration of sequences.

Check each blueprint for internal consistency in the content presented. For example, make sure that prescriptive principles are all stated prescriptively.

Lay the blueprints side by side to determine whether the different sequencing strands can be integrated. Compare the epitome of one type of content to the epitome of the other type(s). If the epitomes are related (address the same topic), move to the Level-1 elaborations and repeat the comparisons.

If the Level-1 elaborations of one content orientation do not appear to be closely related to the Level-1 elaborations of a different content orientation, check to see whether rearranging the Level 1 lessons in one blueprint will allow a closer correspondence between the two (or three) sequences. Do not shift lessons between levels (e.g. do not switch a Level-1 lesson with a Level-2 lesson), unless you can redesign a whole sequencing strand in such a way that it is still consistent with Elaboration Theory prescriptions.

If the content orientations cannot be made to correspond in the epitomes and Level-1 elaborations, sequence the course according to the primary content orientation. Use the other elaboration blueprints as guidelines to ensure that all the necessary supporting content is included in the final sequence blueprint.

If the epitomes and Level-1 elaborations can be made to correspond, proceed by checking for parallels in subsequent levels of elaboration. Note that the blueprints do not have to match lesson-by-lesson. It is possible, for example, to have one lesson of principles serve as the basis for several procedural lessons.

If you determine that the types of content can be taught in simultaneous elaboration, decide whether to integrate or collate the strands, and design your within-lesson sequences accordingly. Remember that principles should be presented before procedures, and prerequisite content should be presented before the content for which it is prerequisite.

Draw up a master sequencing blueprint which shows all of the content in the sequence in which it should be presented, including both the sequence of lessons and the within-lesson sequences.

NEED FOR FURTHER STUDY

While the results of this project do indicate that it is possible to develop elaboration sequences for different content orientations and to teach these in parallel, the findings and conclusions reported in this paper are based upon analysis of only one course. Further study is needed to determine whether these findings are generalizable to other course content. Additionally, this paper is based upon a theoretical analysis of course content. While simultaneous elaboration of different content strands appears theoretically sound, the sequencing reported above has not been subjected to field testing with students.

The decision to sequence the three strands in a collated rather than integrated manner was based upon the SME's insight into the practical constraints of instruction. Other subject matter which does not require physical manipulation of large pieces of equipment may be more adaptable to integrating the content strands. Again, field testing of these two types of within-lesson sequences could provide valuable insight into the optimal instructional presentation.

An additional area in need of further study is that of courses with a significant amount of conceptual content. In this project, as procedures became more complex, the principles required to reinforce the procedures also grew more complex, thus allowing for integration of the elaboration sequences. However, these results may be due to the nature of the two content orientations utilized in this project. It is unclear whether such precise parallels in content complexity can be attained when sequencing courses with conceptual and theoretical (or conceptual and procedural) content.

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Appendix A

Simplifying Assumptions Method

1. Work with a Task Expert (TE) and an Experienced Instructor (EI) to identify the procedural content for the first module--the epitome.

1.1 Identify and describe the simplest, representative, real-world case which the TE has ever performed.

1.1.1 Ask a TE what major activities characterize a representative (typical) performance of the task, and list them.

1.1.2 Ask the TE to recall the simplest performance he or she ever did which contained the most representative activity(ies), and describe them in a flowchart.

1.1.3 Ask the TE to identify the conditions which distinguish this simple case from more complex cases, and list all of them. These are called the "simplifying assumptions".

1.1.4 Further analyze this "epitome" of the procedure by asking an Experienced Instructor (EI) to break each step down to the level on which he or she would teach it. This entails breaking each step into simpler component substeps until the steps are listed at the level of entering knowledge of the target learners (see ETAP's procedural analysis). The EI makes it unnecessary to perform a learner analysis to identify the level of entering knowledge. Flowchart the lowest level of description of this epitome.

1.1.5 Ask the EI to estimate how long it would take to teach the target learners how to do the resulting "epitome" of the procedure (at the use-a-generality level), complete with all the necessary and highly relevant supporting content.

If it is about 10 hours, the epitome is the right size, so list the steps and simplifying assumptions on a macro blueprint and go directly to step 2.
If it is much less than about 10 hours you should increase the size of the epitome by relaxing one of the simplifying assumptions. Pick the one which has eliminated the most important, most representative activity from the epitome.
If it is much more than about 10 hours, continue with step 1.2 to further simplify the epitome.

1.2 If further simplification is necessary, identify and describe the simplest representative case which exists in the real world (regardless of whether the TE has ever performed it).

1.2.1 Ask the TE to think of any possible real-world cases which are simpler than the one identified in step 1.1 above, yet are still quite representative of the procedure in general, and describe the simplest one in a flowchart. This should just be a simpler version of the previous flowchart (from step 1.1.2). In other words, some steps should be deleted, but you shouldn't need to add any new steps. (If you do add some, they should be fewer than the number you delete.)

1.2.2 Ask the TE to identify the additional simplifying assumptions which distinguish this simple case from the previous epitome, and add them to the list of simplifying assumptions.

1.2.3 Make sure that all steps in this new "epitome" of the procedure have been analyzed down to the level of entering knowledge of the target learners (see ETAP's procedural analysis), and that the lowest level of description of this epitome has been flowcharted. Usually no further analysis will be necessary, because new steps are not usually added in 1.2 -- you just delete some.

1.2.4 Ask the EI to estimate how long it would take to teach the target learners how to do the resulting "epitome" of the procedure (at the use-a-generality level), complete with all the necessary and highly relevant supporting content.

If it is about 10 hours, the epitome is the right size, so list the steps and simplifying assumptions on a macro bluepr... and go directly to step 2.
If it is much less than about 10 hours, you should increase the size of the epitome by relaxing one of the simplifying assumptions. Pick the one which has eliminated the most important, most representative activity from the ep'tome.
If it is much more than about 10 hours, continue ' h step 1.3 to further simplify the epitome.

1.3 If further simplification is necessary, identify artificial constraints which further simplify the simplest representative real-world task until it is simple enough to teach in a single lesson.

1.3.1 Ask a TE to think of any artificial constraint(s) which could be imposed to further simplify the epitome identified in step 1.2 above, while still keeping it as representative as possible of the procedure in general, and add it (them) to the list of simplifying assumptions.

1.3.2 Ask a TE to describe the resulting new epitome in a flowchart. This should just be a simpler version of the previous flowchart (from step 1.2.1).

1.3.3 Make sure that all steps in this new "epitome" of the procedure have been analyzed down to the level of entering knowledge of the target learners (see ETAP's procedural analysis), and that the lowest level of description of this epitome has been flowcharted. This further analysis should already have been done in step 1.1.4.

1.3.4 Ask the EI to estimate how long it would take to teach the target learners how to do the resulting "epitome" of the procedure (at the use-a-generality level), complete with all the necessary and highly relevant supporting content.

If it is about 10 hours, the epitome is the right size, so list the steps and simplifying assumptions on a macro blueprint and go directly to step 2.

If it is much less than about 10 hours, you should increase the size of the epitome by relaxing one of the simplifying assumptions. Pick the one which has eliminated the most important, most representative activity from the epitome.
If it is much more than about 10 hours, repeat step I.3 to further simplify the epitome.

2. Work with a TE to identify the procedural content for the next more complex elaboration (lesson).

2.I Decide which of the simplifying assumptions has eliminated the (next) most important, most representative activity from the procedure. If you did either step 1.3 or 1.2 above, its simplifying assumptions will probably be the ones.

2.2 Identify and describe the additional steps which must be performed when that simplifying assumption is relaxed, and describe them in a flowchart.

2.3 Further analyze this "elaboration" of the epitome by asking the EI to break down each step and substep until they are at the level of entering knowledge of the target learners (see ETAP's procedural analysis). Flowchart the lowest level of description of this elaboration.

2.4 Ask the EI to estimate how long it would take to teach the target learners how to do the resulting elaboration of the epitome (at the use-a-generality level), complete with all the necessary and highly relevant supporting content.

If it is about 10 hours, the elaboration is the right size, so list the steps and simplifying assumptions on a macro blueprint and go directly to step 3.
If it is much less than about 10 hours, you should increase the size of the elaboration by relaxing another of the simplifying assumptions. To do this, repeat step 2.
If it is much more than about 10 hours, see if there are any "subordinate" simplifying assumptions which can be applied within the realm of the one which has just been relaxed. Use the activities described in step I to do this.

3. Repeat step 2 until the desired level of complexity has been reached (as specified by the objectives of the course, derived from the needs analysis).

4. If learner control over sequencing is desired, identify the level of elaboration for each lesson by identifying which lesson it elaborates directly on (i.e. which lesson must be learned immediately before it can be learned). Enter this information on the macro blueprint.

5. Work with the EI to identify all necessary and highly relevant supporting content for each lesson in the macro blueprint, and list it in the blueprint. Be sure to include all highly relevant principles and concepts, as well as all learning prerequisites (usually just concepts) for the procedural content and the other supporting content. Also be sure to include all highly relevant information, motor skills, attitudes, and cognitive strategies.

Appendix B

Procedure for Pain Management

Lesson Level	Organizing content	Supporting content	Assumptions
Evaluation/Hot Packs 1 Epit	1. Evaluate pain 2. Review potential treatments 3. Select the best treatment 4. Explain treatment to patient 5. Position patient 6. Check equipment for correct temperature 7. Remove pack, place in toweling 8. Place pack over skin 9. Remove pack after treatment period 10. Check patient for adverse reaction to treatment. 11. Reassess level of pain	Conduction as mech. for heat transfer	A. Electrical stimulation contra-indicated cuts steps 61-74 B. Patient has pain across broad proximal area; cuts steps 12-21 C. No whirlpools available cuts steps 30-36 D. No fluidotherapy available cuts steps 22-26 E. No infrared heating unit cuts steps 40-43 F. Patient has aversion to cold cuts steps 44-57. G. No FDA approval for laser cuts steps 89-93 H. Patient has plastic inserts cuts steps 75-83 I. Patient has metal inserts cuts steps 84-91
Paraffin 2 1	12. Check temp. of paraffin 13. Remove moisture, jewelry from the treatment area 14. Dip part to be treated in wax and remove 15. Allow wax to harden 16. Check for cracks in wax 17. Repeat dipping procedure 8 - 10 times 18. Wrap treated part in plastic 19. Insulate with layer of toweling 20. Position patient with treated part elevated 21. Remove wrapping/wax following treatment period		Relax assumption B; adds steps 12-21

Lesson Level		Organizing content	Supporting content	Assumptions
Fluidotherapy				
3	1	22. Preheat unit to desired temperature		Relax assumption D; adds steps 22-26
		23. Position part to be treated in unit		
		24. Set treatment time		
		25. Turn unit on		
		26. Set agitation		
		27. Remove parts from unit following treatment/ wipe off cellex		
		28. Position therapist's hands in unit		J. Movement during treatment Indicated and patient requires assist. Adds steps 28-29
		29. Assist patient in desired movements		
Hydrotherapy				
4	2	30. Fill tank with water at desired temp		Relax assumption C, adds steps 30-31, 35-39
		31. Check ground fault interrupt		
		35. Position part in water		
		36. Turn turbine on, adjust aeration		
		37. Adjust agitation		
		38. Assist patient in treatment movements as indicated		
		39. Remove and dry part following treatment		
		32. Position patient on hydrolic lift		K. Patient has multiple parts to treat, adds steps 32-34
		33. Transfer patient to full body tank		
		34. Monitor vital signs		
Infrared				
5	1	40. Position infrared unit for uniform application	Radiative heat Cosine Law	Relax assumption E; adds steps 40-43
		41. Position height of lamp for desired dosage	Inverse Square Law	
		42. Turn lamp on		
		43. Turn lamp off after treatment period		

Lesson	Level	Organizing content	Supporting content	Assumptions
Cryotherapy				
6	1	44. Remove cold pack from freezer 45. Wrap pack in damp towel 46. Apply pack to skin 47. Insulate pack with towels 48. Remove pack following treatment period 49. Fill tub with ice/water to desired temperature 50. Immerse part to be treated 51. Assess patient's tolerance of treatment 52. Remove part when numbness is achieved 53. Remove ice cup from freezer 54. Peel back cup to expose ice 55. Apply to skin maintaining movement of ice over surface 56. Wipe up water drips 57. Stop treatment when numbness is achieved	Mechanism of cooling	Relax assumption F; adds steps 44-57 L. Pain is in proximal part cuts steps 49- 52. M. Pain is over large area, cuts steps 53-57. Relax assumption L; adds steps 49-52 as substitute for 44-48. Relax assumption M; adds steps 53-57 as substitute for 49-52
Transcutaneous Electrical Nerve Stimulation (TENS) I				
7	1	63. Select electrode placement sites 64. Determine electrode placement sites 65. Apply electrodes 66. Set pulse rate 67. Set pulse width 68. Set intensity		Relax assumption A; adds steps 63-68 N. Patient has had TENS before deletes steps 61-65 O. Patient achieves pain relief immediately, deletes steps 69-71.
TENS II				
8	1	58. Apply small electrode to patient's finger 59. Apply second electrode to patient's lateral wrist 60. Set parameters to conventional settings. 61. Increase intensity to tolerance 62. Demonstrate effectiveness by checking patient's sensation after 10 minutes of stimulation 69. Adjust pulse width 70. Adjust pulse rate 71. Change electrode sites		Relax assumption N; adds steps 61-65 Relax assumption O; adds steps 69-71 P. Patient continues to have pain adds steps 94-103.

Lesson	Level	Organizing content	Supporting content	Assumptions
Ultrasound				
9	2	72. Apply conductant to skin	Mechanism of heating - cellular oscillation	Relax assumption H, adds steps 72-80 Q. Part to be treated is not boney, cuts steps 78-80
		73. Apply sound head to conductant		
		74. Move sound head		
		75. Set intensity/treatment timer		
		76. Maintain movement of sound head throughout treatment		
		77. Following treatment, turn unit off, wipe off conductant		Relax assumption Q; adds steps 78-80 as substitute for 72-77
		78. Fill plastic tub with water		
		79. Immerse part to be treated and sound head in water		
		80. Maintain uniform distance between sound head and skin surface		
Diathermy				
10	4	81. Remove metal from treatment area	Principles of heating through electromagnetic radiation.	Relax assumption I, adds steps 81-88
		82. Determine treatment dosage		R. Pt is obese, eliminates step 88
		83. Layer toweling over area to be treated	Capacitative heating	
		84. Position air-spaced plates		
		85. Turn unit/timer on		
		86. Tune unit to patient		
		87. Set intensity		Relax assumption R, deletes step 84. adds step 88
		88. Position applicator over area to be treated	Inductive heating	
Laser				
11	4	89. Turn laser on	Physical properties of laser	Relax assumption G; adds steps 89-93 as substitute for 81-88
		90. Select treatment points		
		91. Set desired intensity		
		92. Set timer		
		93. Press control to discharge stimulation		

Lesson	Level	Organizing content	Supporting content	Assumptions
Neuroprobe 12	4	94. Turn neuroprobe on 95. Select pulse rate 96. Select treatment duration 97. Select treatment points 98. Apply pad electrode to distant part of patient 99. Locate low-resistance points of skin 100. Apply point electrode to skin surface 101. Press switch to start stimulation 102. Rapidly increase intensity to patient's tolerance 103. Repeat at remaining points		Relax assumption P, adds steps 94-103 as substitute for 89-93.

Appendix C

Pain Management- Theoretical Blueprint

Lesson	Level	Elaborates on	Content	
Characteristics of Pain				
1	Epitome	- - - -	Pain assessment	1.1. Pain is manifested in the characteristics of intensity, location, quality and behavior.
			Pain Spasm Cycle	1.2. Pain causes muscle spasm Muscle spasm causes ischemia Ischemia causes pain
			Pain Modulation	1.3. Pain is modulated through three levels: presynaptic inhibition at the dorsal horn, descending inhibition, and endorphins
Factors Affecting Pain				
2	1	Epitome 1.1	A. An individual's sociocultural background influences his/her perception of pain intensity.	
			B. The perceived quality of pain is governed by the source and type of noxious stimuli, and its effect on autonomic responses.	
			C. Pain behavior is governed by the source and type of noxious stimuli.	
			D. Referred pain is caused by pathologies in distinctly different parts of the body.	
Pain Spasm Cycle				
3	1	Epitome 1.2	A. Muscle tightness in response to pain is theorized to be caused by a reflex arc involving alpha and gamma motoneurons.	
			B. Ischemia results in decreased fluid exchange, which causes a build up of metabolic exudates.	
			C. Metabolic exudates give rise to pain through activation of nociceptive chemoreceptors.	

Lesson	Level	Elaborates on	Content
Pain Modulation I			
4	1	Epitome 1.3	A. Activation of presynaptic inhibition at the dorsal horn results in immediate, but short-lasting relief of pain.
			B. When nonnociceptive afferents are stimulated, an interneuron releases enkephalin at the dorsal horn synapse of small diameter fibers.
			C. Enkephalin binds with the opiate receptors at the dorsal horn, preventing release of the nociceptive fibers' neurotransmitter.
			D. Deactivation of the nociceptive synapse causes pain transmission to be interrupted at the dorsal horn.
			E. Enkephalin has a short half-life, resulting in short-lasting relief of pain.
Pain Modulation II			
5	2	Lesson 4	A. Activation of the descending inhibition mechanism of pain modulation results in delayed, but long-lasting relief of pain.
			B. Stimulation of small diameter fibers causes descending inhibition of pain.
			C. Recruitment of C and A delta fibers stimulates mechanisms in the periaqueductal grey and raphe nucleus which cause activation of a descending inhibitory interneuron in the dorsolateral tracts.
			D. The descending interneuron secretes serotonin at the dorsal horn. Serotonin binds with the opiate receptors at the dorsal horn, preventing release of the nociceptive neurotransmitter substance.
			E. Serotonin has a longer half-life than enkephalin, resulting in longer lasting relief of pain

Lesson	Level	Elaborates on	Content
Pain Modulation III			
6	3	Lesson 5	A. Activation of the endorphin mechanism of pain modulation results in fast and long-lasting relief of pain.
			B. When the optimal stimuli for activation of the endorphin mechanism of pain modulation occurs, the B-lipotropin/ACTH molecules are broken down in the anterior pituitary.
			C. B-lipotropin converts to endorphins, which causes systemic relief of pain as the endorphin binds with opiate receptor sites at the dorsal horn.
			D. The long half-life of endorphin causes long lasting relief of pain.
			F. Endorphin stimulates the periaquectual grey and raphe nucleus, which causes activation of the descending inhibition mechanism of pain reduction.
			G. ACTH acts at the adrenal gland to stimulate production of cortisol and corticosteriods.
			H. Cortisol and corticosteriods act on the hypothalamus, which exerts an unknown effect on the pituitary gland, causing further breakdown of B-lipotropin/ACTH.

Appendix D

Theoretical Blueprint - Principles Related to Agent Application

Lesson	Level	Elaborates on	Content
Effects of Heat on Pain			
1	Epitome	- -	Heat transmitted to or from the body through dosages of physical agents stimulates sensory nerves causing a reduction of pain. Physical agents transfer heat to or from the body through conduction and radiation. Heat causes a decrease in pain by breaking into the pain-spasm cycle through reduction of ischemia, direct reduction of pain, and through reduction of tissue ischemia. As tissue temperatures increase, blood flow to the heated area increases.
Heat Transfer - Conduction			
2	1	Epitome	Conduction of energy occurs when an object (or tissue) of high energy is placed in direct contactwith an object or tissue) of relatively lower energy. Energy is transferred from objects with relatively higher energy to objects with relatively lower energy. An increase in particle movement causes an increase in the temperature of that particle. Kinetic energy is transformed into thermal energy when particles move and collide with each other generating friction. The rate of heat gained or lost by a tissue through conduction is related to the thickness of the tissue, the temperature gradient, the size of the area being heated or cooled, and the thermal conductivity of the tissues. The rate of heat gained or lost by a tissue through conduction is inversely proportional to the thickness of the tissues. The depth of tissue heating or cooling via conduction is directly related to the length of application of the agent, the thermal conductivity of the tissues, and is inversely related to the thickness of the tissues.

Lesson	Level	Elaborates on	Content
Effect of Cold on Pain			
3	1	Epitome	When a cooling agent is applied to the skin heat is transferred from the tissues to the cooling agent via conduction, thereby decreasing tissue temperature. A decrease in tissue temperature causes a decrease in pain by elevating the pain threshold and by reducing secondary tissue ischemia. When tissues are cooled the metabolic rates of those tissues are slowed, resulting in decreased production of metabolic exudates which can give rise to pain. Cold causes a decrease in blood flow to cooled tissues via reflex vasoconstriction, increased blood viscosity, direct action on smooth muscles in vessel walls, and a decrease in vasodilator metabolites.
Heat Transfer - Radiation			
4	1	Epitome	Transfer of energy through radiation occurs when energy is transferred from one object to another object without direct contact. Heating a tungsten or carbon filament causes emission of infrared radiation. The depth of penetration of radiant energy is directly related to the frequency of the source of radiation . The intensity of radiant energy is directly proportional to the frequency of the radiation. The intensity of radiant heating s inversely proportional to the square of the distance between the source of radiation and the surface being heated, and directly proportional to the wattage of the heating element. The intensity of radiant energy is decreased as the angle of incidence varies from 90 degrees.

Lesson	Level	Elabs on	Content
Electrical Stimulation			
5	1	Epitome	Electrical current applied to the skin in sufficient dosages causes depolarization of peripheral nerves, resulting in sensory perception which can lead to a reduction of pain through presynaptic inhibition at the dorsal horn.
			Given sufficient time between pulses, pulsed electrical current applied to the skin causes repetitive depolarization of peripheral nerves at a frequency equal to the frequency of pulses applied.
			The pulse rate, pulse width, and intensity of electrical stimulation affect the quantity and quality of stimulation.
			As the frequency of electrical pulses applied to the skin increases, the comfort of the stimulation increases and tissue impedance decreases.
			As the duration of an electrical pulse is increased, the comfort of the stimulation is decreased.
			As the intensity of electrical stimulation increases, the number of peripheral nerves recruited increases.
Physics of Ultrasound			
6	2	Lesson 2	The application of an alternating electrical voltage to the face of a piezoelectric crystal causes contraction and expansion of the crystal, resulting in sound wave generation.
			Sound energy transmitted to the body via conduction causes generation of heat in the tissues.
			Sound energy transmitted to the skin causes cells and particles to oscillate at the same frequency as the sound source.
			As sound energy travels through tissues its intensity decreases as the energy is reflected, refracted or absorbed.
			Tissues with high collagen content absorb a greater amount of sound energy than tissues with lower collagen content.
			As the frequency of sound increases, absorption of sound energy by tissues increases.
			As sound frequency increases, the sound energy lost through divergence decreases.
			As sound frequency increases, the depth of penetration of energy into the tissues decreases.

Lesson	Level	Elabs on	Content
7	2	Lesson 3	Physics of Diathermy. Shortwave diathermy is generated by rapidly alternating electrical current oscillating electrons at 27.12 MHz. Constantly varying electric and magnetic fields generates energy that moves through space, transmitting heat via radiation. High frequency alternating current applied to human tissues causes ionic motion of tissues within the field. When a high frequency alternating current is passed through a solenoid coil into a large volume conductor such as a limb, eddy currents are induced in the tissues. Dipoles within an electric field will rotate back and forth as the field changes. When an electrical field is applied to a substance with nonpolar molecules, the electron cloud of individual molecules distorts, creating induced dipoles which oscillate with the alternating current of the field. The motion of electrical charges causes a magnetic field to act at right angles to the direction of motion. Absorption of electric or magnetic field energy causes an increased tissue temperature. Capacitative applicators deliver primarily electrical energy to the tissues. Inductive applicators deliver primarily magnetic energy to the tissues. Electrical field energy is absorbed by fat and skin. Magnetic field energy is absorbed by tissues with high electrolyte content, such as muscles and blood.

Lesson	Level	Elabs on	Content
Electrical Stimulation II			
8	2		Lesson 4 Given equidistance from the stimulation source, large diameter nerve fibers will be recruited before smaller diameter fibers. The internal resistance of nerve fibers is inversely proportional to the fiber size. Electrical stimulation applied through the skin recruits nerve fibers in the reverse order of normal recruitment. The amount of current transmitted to peripheral nerves via electrical stimulation is directly related to the voltage generated and inversely related to tissue impedance. As the frequency of electrical stimulation pulses increases, tissue impedance decreases. The pulse duration and intensity of electrical stimulation affects the type of peripheral nerves activated. Recruitment of small diameter fibers (C and A delta) is hypothesized to cause reduction of pain through descending inhibition. Recruitment of large diameter fibers (A beta) is hypothesized to cause reduction of pain through presynaptic inhibition at the dorsal horn.
Physics of Laser			
9	3	Lesson 6	When a photon is absorbed by an atom, the energy in the orbital electrons is increased resulting in an "excited atom". When an excited atom is struck by another photon, the atom is stimulated to release it's excess energy. Laser is produced when electrons held within a chamber with a semipermeable membrane are stimulated by an external power source at a rapid rate, resulting in stimulated emission of radiation. The dosage of laser delivered to the tissues is dependant upon the laser's power and the time over which energy is transmitted. The amount of laser energy absorbed by the skin is proportional to the absorption quality of the tissue. The depth of laser penetration is directly related to the frequency of the laser. Low power laser is hypothesized to cause pain reduction by a breakdown of metabolic exudates which cause pain.

Appendix E

Procedure for Pain Management

Lesson	Level	Organizing content	Assumptions
Evaluation/Hot Packs			
1	Epit	1. Evaluate pain 8. Review potential treatments 9. Select treatment 10. Explain treatment to patient 11. Position patient 12. Check equipment for correct temperature 13. Remove pack, place in toweling 14. Place pack over skin 15. Remove pack after treatment period 137. Check patient for adverse reaction to treatment. 138. Reassess level of pain	A. Electrical stim. contraindicated, cuts steps 70-81,100-108,116-136 B. Patient has pain across broad proximal area; cuts steps 16-25 C. Patient has infected wound in area to be treated, cuts steps 26-35 D. No fluidotherapy unit available, cuts steps 36-43 E. Part to be treated is curved, cuts steps 66-69 F. Patient has aversion to cold cuts steps 44-57 G. No FDA approval for use of laser, cuts steps 109-115 H. Patient has plastic inserts cuts steps 83-91 I. Patient has metal inserts cuts steps 92-99 J. Patient is unable to explain pain, cuts steps 2-5 K. Patient unable to tolerate palpation cuts steps 6-7 L. Patient is not in subacute stage of healing, cuts steps 58-65
Paraffin			
2	1	16. Check temp. of paraffin 17. Remove moisture, jewelry from treatment area 18. Dip part to be treated in wax and remove 19. Allow wax to harden 20. Check for cracks in wax 21. Repeat dipping procedure 8 - 10 times 22. Wrap treated part in plastic 23. Insulate with layer of towel 24. Position patient with treated part elevated 25. Remove wrapping/wax following treatment	Relax assumption B; adds steps 16-25 as substitute for 12-14

Lesson	Level	Organizing content	Assumptions
Evaluation		II/Hydrotherapy	
3	1	2. Measure pain intensity on VAS	Relax assumption J. Adds steps 2-5
		3. Locate pain on body chart	
		4. Have patient identify adjectives to describe pain	
		5. Question patient regarding specific movements that cause pain	
		26. Fill tank with water at desired temp	Relax assumption C, adds steps 26-38 as substitute for 16-25
		27. Check ground fault interrupt	M. Patient has proximal parts to be treated, deletes steps 33-35
		28. Position part in water	
		29. Turn turbine on, adjust aeration	
		30. Adjust agitation	
		31. Assist patient in treatment movements as indicated	
		32. Remove and dry part following treatment	
		33. Position patient on hydrolic lift	Relax assumption M, adds steps 33-35 as substitute for step 28
		34. Transfer patient to full body tank	
		35. Monitor vital signs	
Evaluation		III/Fluidotherapy	
4	1	6. Palpate painful area for muscle tightness	Relax assumption K, adds steps 6-7
		7. Observe functional limitations caused by tightness	
		36. Preheat unit to desired temperature	Relax assumption D; adds steps 36-43 as substitute for 26-35
		37. Position part to be treated in unit	N. Assisted movement during fluidotherapy contraindicated, deletes steps 39-40
		38. Set treatment time	
		41. Turn unit on	
		42. Set agitation	
		43. Remove parts from unit following treatment/ wipe off cellex	
		39. Position therapist's hands in unit	Relax assumption N, adds steps 39-40
		40. Assist patient desired movements	

Lesson	Level	Organizing content	Assumptions
Cryotherapy			
5	1	44. Remove cold pack from freezer 45. Wrap pack in damp towel 46. Apply pack to skin 47. Insulate pack with towels 48. Remove pack following treatment period	Relax assumption F; adds steps 44-57 as substitute for 36-43 O. Pain is in proximal part, cuts steps 49-52 P. Pain is over large area, cuts steps 53-57
		49. Fill tub with ice/water to desired temperature 50. Immerse part to be treated 51. Assess patient's tolerance of treatment 52. Remove part when numbness is achieved	Relax assumption O, adds steps 49-52 as substitute for 44-48
		53. Remove ice cup from freezer 54. Peel back cup to expose ice 55. Apply to skin maintaining movement of ice over surface 56. Wipe up water drips 57. Stop treatment when numbness is achieved	Relax assumption P; adds steps 53-57 as substitute for 52-55
Contrast Baths			
6	2	58. Prepare warm and cold water baths 59. Immerse part to be treated in warm water for 2 minutes 60. Remove part from warm water and insert in cold water for 1 min. 61. Repeat, alternating warm and cold 4 times beginning and ending with warm.	Relax assumption L. Adds steps 58-65 as substitute for 53-57 Q. Subacute area to be treated is distal deletes steps 62-65
		62. Prepare hot and cold packs 63. Cover part to be treated with hot pack for 2 min 64. Remove hot pack and replace with cold pack for 1 min. 65. Repeat, alternating heat and cold 4 times beginning and ending with heat.	Relax assumption Q, Adds steps 62-65 as substitute for 58-61

Lesson	Level	Organizing content	Assumptions
Infrared			
7	1	66. Position infrared unit for uniform application 67. Position height of lamp for desired dosage 68. Turn lamp on 69. Turn lamp off after treatment period	Relax assumption E, adds steps 66-69 as substitute for 62-65
Transcutaneous Electrical Nerve Stimulation (TENS) I			
8	1	75. Select electrode placement sites 76. Apply electrodes 77. Set pulse rate 78. Set pulse width 79. Set intensity	Relax assumption A; adds steps 70-82, 100-108, 116-136 as substitute for 66-69 R. Patient has had TENS before, deletes steps 70-74 S. Patient does not tolerate noxious stim, cuts steps 116-136 T. Patient achieves satisfactory pain relief, deletes steps 80-82. U. Patient does not have deep muscle spasm associated with pain, deletes steps 100-108
TENS II			
9	2	70. Apply small electrode to patient's finger 71. Apply second electrode to patient's lateral wrist 72. Set parameters to conventional settings. 73. Increase intensity to tolerance 74. Demonstrate effectiveness by checking sensation after 10 minutes of stimulation	Relax assumption R; adds steps 70-74
		80. Adjust pulse width 81. Adjust pulse rate 82. Change electrode sites	Relax assumption T, adds steps 80-82

Lesson	Level	Organizing content	Assumptions
Ultrasound			
10	2	83. Apply conductant to skin 84. Apply sound head to conductant 85. Move sound head 89. Set intensity and timer 90. Maintain movement of sound head throughout treatment 91. Following treatment, turn unit off, wipe off conductant	Relax assumption H, adds steps 83-91 as substitute for 70-82 V. Part to be treated is not boney, cuts steps 86-88
		86. Fill plastic tub with water 87. Immerse part to be treated and sound head in water 88. Maintain uniform distance between sound head and skin surface	Relax assumption V; adds steps 86-88 as substitute for 83-84
Diathermy			
11	2	92. Remove metal from treatment area 93. Determine treatment dosage 94. Layer toweling over area to be treated 95. Position air-spaced plates 96. Turn unit/timer on 97. Tune unit to patient	Relax assumption I, adds steps 92-99 as substitute for 86-91 W. Pt is obese, deletes step 99
		98. Set intensity 99. Position applicator over area to be treated	Relax assumption W, adds step 99 as substitute for 95
Ultrasound/Electrical Stimulation Combined			
12	2	100. Position inactive electrode 101. Set unit to US/E-Stim combination 102. Apply conductant gel 103. Position sound head in contact with skin 104. Turn unit on/set timer 105. Move sound head maintaining contact with skin 106. Set ultrasound intensity 107. Set electrical stimulation intensity. 108. Maintain movement of sound head over skin throughout treatment session.	Relax assumption U, adds steps 100-108 as substitute for 92-94 and 96-99

Lesson	Level	Organizing content	Assumptions
Laser			
13	2	109. Turn laser on 110. Select treatment points 111. Set desired intensity 112. Set timer 113. Apply laser probe to treatment point 114. Press control to discharge stimulation 115. Repeat steps 113-114 until all selected treatment points are treated.	Relax assumption G; adds steps 109-115 as substitute for 100-108
Neuroprobe			
14	3	116. Turn neuroprobe on 117. Select pulse rate 118. Select treatment duration 119. Select treatment points 120. Apply pad electrode to distant part of patient 121. Locate low-resistance points of skin 122. Apply point electrode to skin surface 123. Press switch to start stimulation 124. Rapidly increase intensity to patient's tolerance 125. Repeat at remaining points	Relax assumption S, adds steps 116-136 as substitute for 109-115 X. Patient receives adequate pain relief with neuroprobe alone, cuts steps 126-136
Laser/Neuroprobe Combined			
15	2	126. Turn on neuroprobe/laser 127. Set laser intensity 128. Set neuroprobe parameters 129. Set unit for electrical stim/laser combination 130. Select treatment sites 131. Apply inactive electrode to patient's skin 132. Use point electrode to find low-resistance points at treatment sites. 133. Press switch to start electrical/laser stimulation 134. Rapidly increase electrical stimulation intensity to patient tolerance. 135. Hold point electrode in place for duration of stimulation 136. Repeat at remaining treatment sites	Relax assumption X, adds steps 126-136 as substitute for 116-125

Appendix F

Pain Management- Prescriptive Theoretical Blueprint

Lesson	Level	Elaborates on	Content
Evaluation/Pain Spasm Cycle			
1	Epitome	--	1.1 To determine the effects of treatment on a patient's pain, assess the intensity, location, quality and behavior of the pain before and after treatment. 1.2 To interrupt the pain spasm cycle, apply physical agents to decrease pain, relieve ischemia, or reduce muscle spasm. Pain causes a reflexogenic increase in muscle tightness. Ischemia results in decreased fluid exchange, which causes a build up of metabolic exudates. Metabolic exudates give rise to pain through activation of nociceptive chemoreceptors.
Pain Modulation I			
2	1	Epitome	To achieve immediate but short-lasting relief of pain apply physical agents to stimulate non-nociceptive fibers to activate presynaptic inhibition at the dorsal horn. When nonnociceptive afferents are stimulated, an interneuron releases enkephalin at the dorsal horn synapse of small diameter fibers. Enkephalin binds with the opiate receptors at the dorsal horn, preventing release of the nociceptive fibers' neurotransmitter. Deactivation of the nociceptive synapse causes pain transmission to be interrupted at the dorsal horn. Enkephalin has a short half-life, resulting in short-lasting relief of pain.

Lesson	Level	Elaborates on	Content
Breaking Pain Spasm Cycle			
3	1	Epitome	To relieve ischemia-induced pain apply physical agents which increase blood flow to the ischemic area. An increase in tissue temperature causes the body to release chemical mediators which act on the smooth muscles to cause vasodilation. An increase in cutaneous tissue temperature activates a local spinal cord reflex which decreases postganglionic sympathetic adrenergic nerve activity to smooth muscles of blood vessels, resulting in vasodilation. An increase in skin temperature stimulates cutaneous thermoreceptors, which send sensory afferents through nerve branches to cutaneous blood vessels and cause the release of a vasodilator to cause increased blood flow.
Evaluation II			
4	1	Epitome	A. To increase the objectivity of the measure of pain intensity use a visual analog scale or numerical sequence scale. B. To assess the quality of pain have the patient identify adjectives which describe the pain sensation. C. To gather information regarding the cause of pain, question the patient about how the pain changesthroughout the day. D. To locate the patient's pain have him/her identify the painful areas on a body diagram, or point to the painful area(s).
Breaking Pain Spasm Cycle II			
5	2	Lesson 3	To break the pain-spasm cycle by decreasing muscletightness, apply physical agents which decrease muscle spindle activity. Increasing muscle temperature to 42 degrees Celsius decreases the firing rate of II afferents and increase the firing rate of Ib fibers from Golgi tendon organs. A decrease in firing of II afferents and increased firing of Ib fibers causes a decreased firing of alpha motoneurons. A decrease in alpha motoneuron activity reduces tonic extrafusal fiber activity, resulting in decreased muscle tightness.

Lesson	Level	Elaborates on	Content
Decreasing Pain Using Cold			
6	2	Lesson 3	A. To decrease pain when a patient has inflammation, use cooling agents which activate non-nociceptive afferents to decrease pain and elevate the pain threshold. B. To decrease swelling associated with inflammation, decrease the metabolic rate of the tissues in the inflammed area by applying cooling agents. C. To decrease muscle spasm when inflammation is present, apply cooling agents, which increase apha motoneuron activity and decrease gamma motoneuron activity resulting in decreased muscle tightness. D. To decrease pain associated with inflammation apply cooling agents, which decrease the metabolic rates of tissues, resulting in decreased production of metabolic exudates which can give rise to pain.
Pain Modulation II			
7	2	Lesson 2	To provide delayed but long lasting relief of painstimulate small diameter fibers to activate descending inhibition of pain. Recruitment of C and A delta fibers stimulates mechanisms in the periaqueductal grey and raphe nucleus which cause activation of a descending inhibitory interneuron in the dorsolateral tracts. The descending interneuron secretes serotonin at the dorsal horn. Serotonin binds with the opiate receptors at the dorsal horn, preventing release of the nociceptive neurotransmitter substance. Serotonin has a longer half-life than enkephalin, resulting in longer lasting relief of pain.

Lesson	Level	Elaborates on	Content
Pain Modulation III			
8	3	Lesson 5	To achieve immediate, long lasting relief of pain activate the endorphin mechanism of pain modulation. When the optimal stimuli for activation of the endorphin mechanism of pain modulation occurs, the B-lipotropin/ACTH molecules are broken down in the anterior pituitary. B-lipotropin converts to endorphins, which causes systemic relief of pain as the endorphin binds with opiate receptor sites at the dorsal horn. The long half-life of endorphin causes long lasting relief of pain. Endorphin stimulates the periaquectual grey and raphe nucleus, which causes activation of the descending inhibition mechanism of pain reduction. ACTH acts at the adrenal gland to stimulate production of cortisol and corticosteriods. Cortisol and corticosteriods act on the hypothalamus, which exerts an unknown effect on the pituitary gland, causing further breakdown of B-lipotropin/ACTH. Hyperstimulation is hypothesized to cause activation of the endorphin mechanism of pain modulation.

Appendix G

Theoretical Blueprint - Descriptive Principles Related to Agent Application

Lesson	Level	Elaborates on	Content
Effect of Heat on Pain			
1	Epitome	- - -	Heat transmitted to or from the body through therapeutic dosages of physical agents stimulates sensory nerves causing a reduction of pain.
			Physical agents transfer heat to or from the body through conduction and radiation.
			Heat causes a decrease in pain by breaking into the pain-spasm cycle through reduction of ischemia, direct reduction of pain, and through reduction of tissue ischemia.
			As tissue temperatures increase, blood flow to the heated area increases.
Heat Transfer - Conduction			
2	1	Epitome	Conduction of energy occurs when an object (or tissue) of high energy is placed in direct contact with an object or tissue) of relatively lower energy.
			Energy is transferred from objects with relatively higher energy to objects with relatively lower energy.
			An increase in particle movement causes an increase in the temperature of that particle. Kinetic energy is transformed into thermal energy when particles move and collide with each other generating friction.
			The rate of heat gained or lost by a tissue through conduction is related to the thickness of the tissue, the temperature gradient, the size of the area being heated or cooled, and the thermal conductivity of the tissues. The rate of heat gained or lost by a tissue through conduction is inversely proportional to the thickness of the tissues.
			The depth of tissue heating or cooling via conduction is directly related to the length of application of the agent, the thermal conductivity of the tissues, and is inversely related to the thickness of the tissues.

Lesson	Level	Elaborates on	Content
Effect of Cold on Pain			
3	1	Epitome	When a cooling agent is applied to the skin heat is transferred from the tissues to the cooling agent via conduction, thereby decreasing tissue temperature. The depth of penetration of cooling agents is directly related to the length of exposure to cold. The degree of cooling of tissues is directly related to the size of the area being cooled, the thermal conductivity of the tissues, and inversely related to the thickness of the tissues. Cold causes a decrease in blood flow to cooled tissues via reflex vasoconstriction, increased blood viscosity, direct action on smooth muscles in vessel walls, and a decrease in vasodilator metabolites.
Heat Transfer - Radiation			
4	1	Epitome	Transfer of energy through radiation occurs when energy is transferred from one object to another without direct contact. Heating a tungsten or carbon filament causes emission of infrared radiation. The depth of penetration of radiant energy is directly related to the frequency of the source of radiation . The intensity of radiant energy is directly proportional to the frequency of the radiation. The intensity of radiant heating is inversely proportional to the square of the distance between the source of radiation and the surface being heated, and directly proportional to the wattage of the heating element. The intensity of radiant energy is decreased as the angle of incidence varies from 90 degrees.

Lesson	Level	Elabs on	Content
Electrical Stimulation I			
5	1	Epitome	Electrical current applied to the skin in sufficient dosages causes depolarization of peripheral nerves, resulting in sensory perception which can lead to a reduction of pain through presynaptic inhibition at the dorsal horn.
			Given sufficient time between pulses, pulsed electrical current applied to the skin causes repetitive depolarization of peripheral nerves at a frequency equal to the frequency of pulses applied.
			The pulse rate, pulse width, and intensity of electrical stimulation affect the quantity and quality of stimulation.
			As the frequency of electrical pulses applied to the skin increases, the comfort of the stimulation increases.
			As the duration of an electrical pulse is increased, the comfort of the stimulation is decreased.
			As the intensity of electrical stimulation increases, the number of peripheral nerves recruited increases.
Electrical Stimulation II			
6	2	Lesson 4	Given equidistance from the stimulation source, large diameter nerve fibers will be recruited before smaller diameter fibers.
			The internal resistance of nerve fibers is inversely proportional to the fiber size.
			Electrical stimulation applied to the skin recruits nerve fibers in the reverse order of normal fiber recruitment.
			The amount of current transmitted to peripheral nerves through electrical stimulation is directly related to the voltage generated and inversely related to tissue impedance.
			As the frequency of electrical stimulation pulses increases, tissue impedance decreases.
			The pulse duration of electrical stimulation affects the type of peripheral nerves activated.
			Recruitment of small diameter fiber (C and A delta) is hypothesized to cause reduction of pain through descending inhibition.
			Noxious level stimulation is hypothesized to cause reducation of pain through activation of the endorphin system of pain modulation.

Lesson	Level	Elabs on	Content
Physics of Ultrasound			
7	2	Lesson 2	The application of an alternating electrical voltage to the face of a piezoelectric crystal causes contraction and expansion of the crystal, resulting in sound wave generation.
			Sound energy transmitted to the body via conduction causes generation of heat in the tissues.
			Sound energy transmitted to the skin causes cells and particles to oscillate at the same frequency as the sound source.
			As sound energy travels through tissues its intensity decreases as the energy is reflected, refracted or absorbed.
			Tissues with high collagen content absorb a greater amount of sound energy than tissues with lower collagen content.
			As the frequency of sound increases, absorption of sound energy by tissues increases.
			As sound frequency increases, the sound energy lost through divergence decreases.
			As sound frequency increases, the depth of penetration of energy into the tissues decreases.

Lesson	Level	Elabs on	Content
Physics of Diathermy			
8	2	Lesson 3	Shortwave diathermy is generated by rapidly alternating electrical current oscillating electrons at 27.12 MHz. Constantly varying electric and magnetic fields generates energy that moves through space, transmitting heat via radiation. High frequency alternating current applied to human tissues causes ionic motion of tissues within the field. Dipoles within an electric field will rotate back and forth as the field changes generating heat. When an electrical field is applied to a substance with nonpolar molecules, the electron cloud of individual molecules distorts, creating induced dipoles which oscillate with the alternating current of the field. When a high frequency alternating current is passed through a solenoid coil into a large volume conductor such as a limb, eddy currents are induced in the tissues. The motion of electrical charges causes a magnetic field to act at right angles to the direction of motion. Capacitative applicators deliver primarily electrical energy to the tissues. Inductive applicators deliver primarily magnetic energy to the tissues. Electrical field energy is absorbed by fat and skin. Magnetic field energy is absorbed by tissues with high electrolyte content, such as muscles and blood.
Physics of Laser			
9	3	Lesson 7	When a photon is absorbed by an atom, the energy in the orbital electrons is increased resulting in an "excited atom". When an excited atom is struck by another photon, the atom is stimulated to release it's excess energy. Laser is produced when electrons held within a chamber with a semipermeable membrane are stimulated by an external power source at a rapid rate, resulting in stimulated emmission of radiation. The dosage of laser delivered to the tissues is dependant upon the laser's power and the time over which energy is transmitted. The amount of laser energy absorbed by the skin is proportional to the absorption quality of the tissue. The depth of laser penetration is directly related to the frequency of the laser.

Figure Captions

Figure 1. Final sequence of three content strands. Lesson content is shown by content title. Lessons that do not have new theoretical content involve review of principles covered in prior lessons.

Figure 2. Relationships between theoretical and procedural content. Boxed content is new material to be presented in Lesson 7. Content from prior lessons that is pertinent to Lesson 7 is shown by content title (for prescriptive and descriptive theoretical content) or by step number (for procedural content).

Prescriptive	Descriptive	Procedure
Evaluation/Pain Spasm Cycle Pain Modulation I Breaking Pain Spasm Cycle Evaluation II Breaking Pain Spasm Cycle II	Effect of Heat on Pain Heat Transfer - Radiation	Steps 1-11

Transfer of energy through radiation occurs when energy is transferred from one object to another without direct contact.

Heating a tungsten or carbon filament causes emission of infrared radiation.

The intensity of radiant energy is decreased as the angle of incidence varies from 90 degrees. (Cosine Law)

The depth of penetration of radiant energy is directly related to the frequency of the source of radiation.

The intensity of radiant energy is directly proportional to the frequency of the radiation.

The intensity of radiant heating is inversely proportional to the square of the distance between the source of radiation and the surface being heated, and directly proportional to the wattage of the heating element (Inverse Square Law)

66. Position infrared unit for uniform application
67. Position height of lamp for desired dosage
68. Turn lamp on
69. Turn lamp off after treatment period

Steps 137-138

Prescriptive Theoretical Content	Descriptive Theoretical Content	Procedural Content
Evaluation/Pain Spasm Cycle Pain Modulation I	Effects of Heat	Evaluation/Hot Packs
Breaking Pain Spasm Cycle	Heat Transfer - Conduction	Paraffin
Evaluation II		Whirlpool
Breaking Pain Spasm Cycle II		Fluidotherapy
Decreasing Pain Using Cold	Effects of Cold on Pain	Cryotherapy
REVIEW AND SYNTHESIS OF ALL PRINCIPLES		Contrast Baths
	Heat Transfer - Radiation	Infrared
Pain Modulation II	Electrical Stimulation I	Transcutaneous Electrical Nerve Stimulation I
	Electrical Stimulation II	TENS II
	Physics of Ultrasound	Ultrasound
	Physics of Diathermy	Diathermy
REVIEW AND SYNTHESIS OF PRINCIPLES		Ultrasound/Electrical Stimulation Combined
Pain Modulation III	Physics of Laser	Laser
		Neuroprobe
		Neuroprobe and Laser Combined