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A Case Study on Course Sequencing with Multiple Strands 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 great importance in a course. Through analysis of a course that emphasizes the application of theory to practice in physical therapy treatment, we found it is possible to develop an overall course sequence in which content of different orientations (procedural and theoretical) is presented in parallel elaboration sequences. We also found it is possible to simultaneously elaborate two types of theoretical content (descriptive and prescriptive). We propose that the advantage to parallel elaboration of multiple strands of content is that it will ensure both procedural and theoretical content are 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, which include decisions about what to teach and how to teach it. Regarding the "how," 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 (Gagné, 1977) or understand some aspect of content (Anderson, 1984; Ausubel, Novak & Hanesian, 1978). Hence, such prerequisites should be sequenced earlier than the knowledge for which they are prerequisite. Second, the formation of a schema can greatly facilitate the meaningful assimilation of new material (Anderson, 1984; Ausubel, et al., 1978; Rummelhart & Ortony, 1977) and can thereby enhance both retention and transfer.

In spite of the importance of sequencing, relatively little is known about how to design the best possible sequence. Reigeluth has integrated much of the knowledge generated to date, such as Gagné's (1977) hierarchical sequence, Bruner's (1960) spiral curriculum, Ausubel's (1968) progressive differentiation, and Merrill's (1978) shortest-path sequencing, into a comprehensive set of prescriptions referred to as the elaboration theory (Reigeluth, 1992; Reigeluth & Stein, 1983). He has also developed more operational guidelines on how to design each of the various sequences prescribed (Reigeluth, 1987; Reigeluth & Darwazeh, 1982; Reigeluth & Kim, 1993). And he has conducted formative research on the elaboration theory (English, 1992; English & Reigeluth, in final preparation). This research has supported the elaboration theory's hypothesis that a carefully designed elaboration sequence will result in more motivational and effective instruction.

Reigeluth's work was born out of a concern about the piecemeal "parts-to-whole" instructional sequences that resulted from applying Gagné's hierarchical sequence methodology. His goal was to develop more holistic sequences that would 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 & Kim, 1993; Reigeluth & Rodgers, 1980) is based largely on the work of Scandura (1973) and Merrill (1978). It entails starting with a simple but representative 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; Reigeluth & Kim, 1993) 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 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 great importance in a course, such as a course that focuses on both theory and practice, common in both educational and training contexts. 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 case study was to investigate whether or not it is possible to elaborate two types of content in a given course simultaneously, and, if so, how it might best be done. We felt these questions must be answered before conducting experimental research to test the effectiveness of such a "multiple strands" elaboration sequence.

Methods and Results

To investigate these questions, we decided to design elaboration sequences for two content orientations (theoretical and procedural) in a specific course and then to determine whether the sequences were compatible and could be combined. If so, we would then investigate the effectiveness of this "multiple strands" sequence in a follow-up project.

We selected a course in a physical therapy educational program. The primary goal of the course was to enable the learners to select and use physical agents (heat, cold, electrical stimulation and light) in the management of pain. This course was selected for two reasons. First, the course placed great importance on two different orientations. The content was largely procedural in nature but included heavy emphasis on the scientific basis (theory) of procedure application. Second, the first author was teaching the course at the time and was therefore able to serve the role of both designer and subject-matter expert (SME). In most instances the design of elaboration sequences is performed through the joint effort of a SME and an instructional designer. Due to funding constraints, however, the designer (first author) served as the SME in this project.

This project progressed through four phases. Phases I through III involved designing elaboration sequences for the two (later expanded to three) 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" (more recently called "simplifying conditions") for procedural elaborations. This technique allows one to identify progressively more difficult versions (or paths) of a complex procedure and sequence them in a simple-to-complex manner. To identify the epitome (simplest representative) version, 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 that make the simplest case different from more complex cases are identified. These are the simplifying conditions.

After the steps comprising the epitome are listed and all simplifying conditions are identified, the next simplest version of the procedure is identified for the second lesson in the elaboration sequence. To do this, the SME (subject-matter expert) is asked to identify the simplifying condition that eliminated the most important or representative steps that are missing from the epitome. This condition 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 versions of the procedure are included on a sequence "blueprint" or outline of the course. As the sequence is created, the necessary supporting content is noted on the blueprint to ensure that this content is included in the final sequence. For a more detailed description of the steps involved in developing procedural elaborations using the simplifying conditions method, see Beissner and Reigeluth (1989) and Reigeluth and Kim (1993).

The content selected for this project included a relatively large number of procedures that are loosely interrelated as a complex procedure for administering physical therapy. Each procedure taught precluded the use of other procedures so that even in the most complex version the largest number of new steps (at entry level of description) taught in a single lesson is eighteen. The procedural epitome was selected by identifying the task that was the easiest and most frequently used by physical therapists and that was highly representative of their job of managing pain: application of hydrocollator packs (hot packs). The steps for applying hot packs were identified. Then all of the conditions that would lead a therapist 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 condition in the epitome was that a patient had pain over a broad, proximal area of the body. Other conditions included the lack of equipment for application of another type of physical agent (such as no fluidotherapy unit available) and the presence of certain medical complications (such as previous surgeries which precluded the use of other physical agents).

The purpose of this study was to investigate whether it is possible to elaborate two types of content in a given course simultaneously, and, if so, how it might best be done.

To form the procedural elaboration sequence, the simplifying conditions were relaxed gradually to allow students to learn those procedures that were both easiest and most commonly used before the more complex or less frequently used procedures. Conditions that omitted the easier and more 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 condition first, 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 condition that precluded the use of that procedure was relaxed.) In some instances, relaxing a simplifying condition led to several new physical agents being appropriate, or it required too large a number of steps to be taught in a single lesson. In such cases, additional (secondary) simplifying conditions were added when the initial (primary) condition 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 (shown later as a part of Table 1).

Phase II: Theoretical Elaboration

The second phase of the project was to design a theoretical elaboration sequence independently of the procedural sequence. Reigeluth (1987) recommended three methods for designing a theoretical elaboration sequence. One was 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 was to ask the 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) would generally be picked first. The third method was to use a variation of the Simplifying Conditions Method to restrict the complexity of the problem domain and then to analyze the simple problem domain to identify all principles that apply to it. Principles for subsequent elaborations were identified by relaxing the simplifying conditions one at a time in a manner similar to that used for the procedural elaboration sequence (Reigeluth & Kim, 1993).

For the purposes of this project, the second method of sequencing instruction (SME prioritization) was used to create the theoretical blueprint. Since the focus of the course was on the use of physical agents in the management of pain, principles of pain evaluation and the physiological mechanisms for pain control were identified. The principles were sequenced by selecting those principles that were the most fundamental and essential for experts to use, followed by progressively more complex and less intuitive principles.

The theoretical epitome focused on measurement of pain and on factors influencing pain perception. This included an examination of the different aspects of pain (intensity versus quality versus location, etc.) and an overview of the ways the body modifies pain perception. Lesson 2 expanded on the first component of the epitome by detailing specific aspects of pain evaluation for determining the level and type of pain that a given patient experiences. Additional principles introduced at this level of complexity included the body's physiological mechanisms for controlling pain that may be activated through use of the physical agents being taught. Levels two and three of elaboration added further detail to include progressively more complex mechanisms of pain control by addressing neurophysiological mechanisms activated by the physical agents.

The final step in the development of this sequence was the review of 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 for applying physical agents. The additional theoretical content deemed necessary for inclusion in the course was found to be descriptive principles. These principles, which described why the physical agents worked, were used to create a third elaboration sequence independent of the first two sequences. These two types of principles (prescriptive and descriptive) are both likely to be important in both educational and training contexts.

Phase III: Descriptive Theoretical Elaboration

To design the descriptive theoretical elaboration, the previously designed sequences (procedural and prescriptive-theoretical) were set aside and principles that described how the physical agents worked were listed. These principles were then organized into an elaboration sequence by identifying those principles that were the most intuitive and fundamental to the course content, those that would need to 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 and since it is one of the most important and common physical agents. Thus, the epitome included principles related to how heat causes the soothing sensation.

> ***The procedural epitome was selected by identifying the task that was the easiest and most frequently used by physical therapists and that was highly representative of their job of managing pain.***

Subsequent lessons expanded 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 also sequenced by the complexity of the principles presented and by 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 governing the intensity of radiant energy are more complex than principles governing the intensity of conducted energy. Second-level elaborations dealt with increasingly complex principles relevant to previously presented material. In Lesson 4, for example, basic principles of radiant energy emitted from hot sources were presented, while Lesson 8 was 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 requiring instruction were included in the elaboration blueprint.

Phase IV: Integration of Sequences

Upon completion of the three sequences (procedural, prescriptive-theoretical, and descriptive-theoretical), the blueprints were put side by side to determine whether they were compatible enough to be integrated into a single course sequence. Compatibility was determined primarily by the extent to which content in corresponding lessons in each sequence were related to each other (dealt with the same topic). Upon examination of the three blueprints, some gaps were identified. 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.

When put side by side, significant parallels in content among the three sequences were found. To attain a more precise parallel, however, 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 violate any elaboration theory guidelines since the lessons that were interchanged were on the same level of elaboration (level of complexity).

Since it was found that the three elaboration strands (procedures, prescriptive principles, and descriptive principles) could be aligned easily and 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 intermingled in the lesson), or "collated" (i.e., all of the content of one strand's Lesson 1 should be followed by all of the content from the next strand's Lesson 1 and so forth).

A prescriptive-to-descriptive-to-procedure sequence was hypothesized as being the most logical order of presentation because th[e] learner might be most motivated t[o] gain an understanding of the use o[f] a physical agent (prescriptiv[e] theory), then to understand wh[y] those physical agents work (de[scriptive] theory), and finally t[o] learn how to use the physica[l]

Table 1
Final Sequence of Three Content Strands

Lesson Number	Prescriptive Theoretical Content	Descriptive Theoretical Content	Procedural Content
1	Evaluation/Pain Spasm Cycle Pain Modulation I	Effects of Heat	Evaluation/Hot Packs
2	Breaking Pain Spasm Cycle	Heat Transfer - Conduction	Paraffin
3	Evaluation II		Whirlpool
4	Breaking Pain Spasm Cycle II		Fluidotherapy
5	Decreasing Pain Using Cold	Effects of Cold on Pain	Cryotherapy
6	REVIEW AND SYNTHESIS OF RELATED PRINCIPLES		Contrast Baths
7		Heat Transfer - Radiation	Infrared
8	Pain Modulation II	Electrical Stimulation I	Transcutaneous Electrical Nerve Stimulation I
9		Electrical Stimulation II	TENS II
10		Physics of Ultrasound	Ultrasound
11		Physics of Diathermy	Diathermy
12	REVIEW AND SYNTHESIS OF RELATED PRINCIPLES		Ultrasound/Electrical Stimulation Combined
13	Pain Modulation III	Physics of Laser	Laser
14			Neuroprobe
15	REVIEW AND SYNTHESIS OF RELATED PRINCIPLES		Neuroprobe and Laser Combined

Note. Each row represents one lesson in the sequence. Lesson content is shown by content title. Lessons that do not have new theoretical content involve review of principles covered in prior lessons.

agents effectively (procedure). This format of instruction is consistent with, though more precise than, 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 Table 1. The first row of the figure shows the content of the first lesson and so on for each subsequent row. Note that the theoretical and procedural lessons do not match up on a one-to-one basis, for in some instances there is no new theoretical information to be taught. Conversely, the first lesson includes *two* segments from the prescriptive theoretical sequence.

Figure 1 shows the interrelationships among the three types of content for a single lesson (Lesson 7). Blueprints with more detailed content specifications for each of the sequencing strands are shown in the Appendices.

In deciding between collating and integrating the lessons, the collated approach was selected as being more feasible for this course's 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. Therefore, practical constraints prevented integrating (intermingling) the three types of content throughout a single lesson. Furthermore, since the procedures taught involved physical manipulation of equipment, it seemed reasonable to teach the principles related to how the procedure works before actually beginning to teach the procedure itself. This allowed a greater fluidity in the performance of the procedure, provided an additional opportunity to review principles as the procedure was taught, and enhanced safe and proper use of equipment.

For example, in Procedure Lesson 7 (shown in Figure 1), students learned to position patients for treatment and to adjust an infrared heating lamp to provide the correct intensity of heat to the patient. This required 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 numerical 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 would 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 relevant principles.

Conclusions

The results of this case study show that it is possible to have parallel elaboration sequences of different content orientations integrated within a given course. At the outset of this study 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 adjusting of the material was necessary to achieve a good fit. Since many courses in both education and training contexts place considerable importance on several kinds of content (especially procedures and principles), this use of parallel elaboration sequences should have fairly wide utility. 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 none of those content strands is presented in a non-elaborative sequence. Thus each of the content strands presents increasingly complex content. This ensures that the learner progresses from simple to complex principles at the same time that he or she is progressing from simple to complex procedures. English (1992) has found this to be a very effective and motivating sequence.

An additional advantage of a course sequence using parallel elaboration of multiple strands is that, as secondary blueprints are developed,

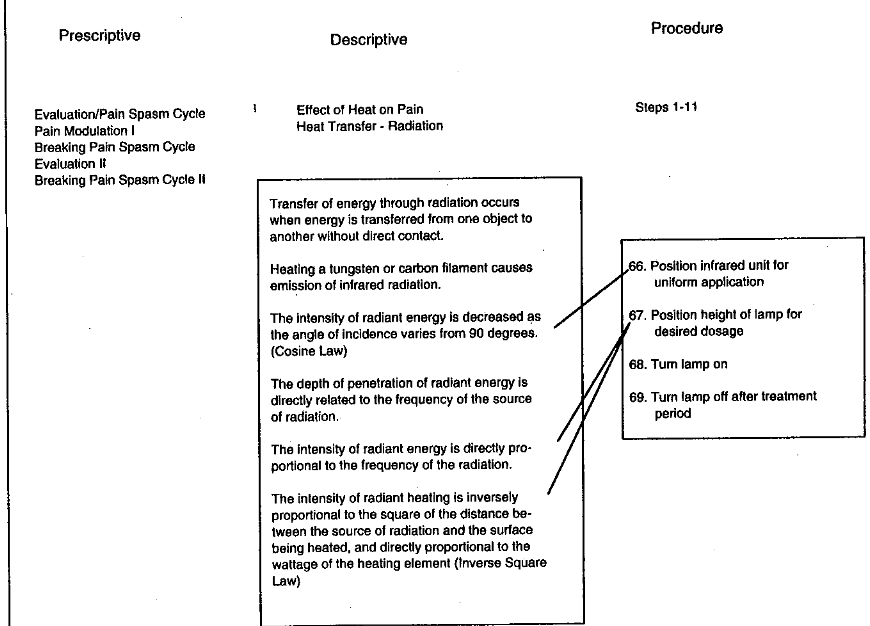

Figure 1. Relationships between theoretical and procedural content for Lesson 7.

material that is missed when the first elaboration sequence is created can be identified and included in the final instructional blueprint. In this project, the process of developing theoretical elaborations reminded the 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.

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 (or causal model) for the same content area. They also acquire knowledge of the interrelationships between the two schemata. Research by others (see e.g., Anderson, 1984; Rummelhart & Ortony, 1977) indicates that the formation of these schemata is likely to enhance the learning of other new procedures and principles and to facilitate 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.

Recommendations

For those interested in trying out the parallel elaboration of multiple strands, the phases and steps shown in Table 2 are presently recommended, based on our experience in this case study. Naturally, further formative research is needed to further develop both the multiple strands sequencing strategy and the procedures for implementing it. And summative (experimental) research is, of course, needed to determine the effectiveness of parallel elaboration of multiple strands compared with other typical sequences, such as the one presented by the textbook for this physical therapy course, or one using Gagné's hierarchical approach.

Future Research

While the results of this case study 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 if these findings are generalizable to other kinds of course content. Additionally, this paper is based upon a logical analysis of a specific course content. While simultaneous elaboration of different content strands appears logically sound, the sequence reported above has not yet been subjected to field testing with students.

The decision to sequence the three strands (prescriptive-theoretical, descriptive-theoretical, and procedural content) in a collated rather than integrated manner was based upon the SME's insight into the practical constraints of the instructional situation. Subject matter that does *not* require physical manipulation of large pieces of equipment may be more adaptable to integrating the content strands. Again, field testing and/or experimental comparison of these two types of within-lesson sequences could provide valuable insights into the optimal instructional presentation.

Table 2 Phases and Steps for Parallel Elaboration of Multiple Content Strands

Phase One: Design the initial elaboration sequence.

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

1.2 Design an elaboration sequence based upon the dominant content orientation (see Reigeluth & Kim, 1993, for details).

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

Phase Two: Design the secondary elaboration sequence.

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

2.2 Design an elaboration sequence based upon this second orientation content (again, see Reigeluth & Kim, 1993).

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

2.4 After the second blueprint is completed, refer back to the initial blueprint. Cross-check to ensure that no important content has been omitted from either blueprint. If you find that additional content needs to be presented, add it to the appropriate blueprint.

2.5 If an additional content orientation should receive considerable emphasis in the course, repeat Phase Two. Otherwise, progress to Phase Three.

Phase Three: Integrate the sequences.

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

3.2 Put 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.

3.3 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 sound principles of elaboration.

3.4 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.

3.5 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 parallel elaboration, form one sequence blueprint that combines the multiple strands.

3.6 Add to the sequence blueprint all of the important supporting content (e.g., concepts, prerequisite skills, understandings, attitudes, information) wherever it is most relevant.

3.7 Decide whether to integrate or collate the strands and design your within-lesson sequences accordingly. Remember that principles should be presented before procedures and that prerequisite content should be presented before the content for which it is prerequisite.

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

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 theoretical and procedural elaboration sequences. However, these results may be due to the nature of the two content orientations utilized in this project. While it seems likely that such precise parallels in content complexity will also be attained when sequencing courses with conceptual and theoretical (or conceptual and procedural) content, this remains to be tested. It is our hope that this study will spur more research in this important area.

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Appendix A
Prescriptive Theoretical Blueprint for Pain Management

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.
				A. Pain causes a reflexogenic increase in muscle tightness.
				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.
				Pain Modulation I
2	1	Epitome	A.	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.
			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.

Lesson	Level	Elaborates on		Content
				Breaking Pain-Spasm Cycle
3	1	Epitome	A.	To relieve ischemia-induced pain apply physical agents which increase blood flow to the ischemic area.
			B.	An increase in tissue temperature causes the body to release chemical mediators which act on the smooth muscles to cause vasodilation.
			C.	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.
			D.	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 changes throughout 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	A.	To break the pain-spasm cycle by decreasing muscle tightness, apply physical agents which decrease muscle spindle activity.
			B.	Increasing muscle temperature to 42 degrees Celsius decreases the firing rate of II afferents and increases the firing rate of Ib fibers from Golgi tendon organs.
			C.	A decrease in firing of II afferents and increased firing of Ib fibers causes a decreased firing of alpha motoneurons.
			D.	A decrease in alpha motoneuron activity reduces tonic extrafusal fiber activity, resulting in decreased muscle tightness.
				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 inflamed area by applying cooling agents.

Lesson	Level	Elaborates on		Content
			C.	To decrease muscle spasm when inflammation is present, apply cooling agents, which increase alpha 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	A.	To provide delayed but long-lasting relief of pain stimulate small diameter fibers to activate descending inhibition of pain.
			B.	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.
			C.	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.
			D.	Serotonin has a longer half-life than enkephalin, resulting in longer-lasting relief of pain.
				Pain Modulation III
8	3	Lesson 5	A.	To achieve immediate, long-lasting relief of pain activate the endorphin mechanism of pain modulation.
			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 periaqueductal 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 corticosteroids act on the hypothalamus, which exerts an unknown effect on the pituitary gland, causing further breakdown of B-lipotropin/ACTH.
			I.	Hyperstimulation is hypothesized to cause activation of the endorphin mechanism of pain modulation.

Appendix B
Descriptive Theoretical Blueprint for 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 and the thermal conductivity of the tissues, and is inversely related to the thickness of the tissues.
			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 and 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.

Lesson	Level	Elaborates on	Content
			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 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.
			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

Lesson	Level	Elaborates on	Content
			hypothesized to cause reduction of pain through descending inhibition. Noxious level stimulation is hypothesized to cause reduction of pain through activation of the endorphin system of pain modulation.
			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.
			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.

Lesson	Level	Elaborates on	Content
			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 its 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 dependent 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.

Appendix C
Procedural Blueprint for Pain Management

Lesson	Level	Organizing Content	Simplifying Condition
		Evaluation / Hot Packs	
1	Epitome	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 s 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.	Relax condition B (adds steps 16-25 as substitute for 12-14).

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

Lesson	Level	Organizing Content	Simplifying Conditions
		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 condition F (adds steps 44-57 as substitute for 36-43), but include secondary condition O, Pain is in proximal part (cuts steps 49-52) and secondary condition 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 secondary condition 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 secondary condition P (adds steps 53-57 as substitute for 49-52).
		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 minute. 61. Repeat, alternating warm and cold 4 times beginning and ending with warm.	Relax primary condition L (adds steps 58-65 as substitute for 53-57), but include secondary condition Q, Subacute area to be treated is distal (cuts 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 secondary condition Q (adds steps 62-65 as substitute for 58-61).
		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 primary condition E (adds steps 66-69 as substitute for 62-65).

Lesson	Level	Organizing Content	Simplifying Conditions
8	1	***Transcutaneous Electrical Nerve Stimulation (TENS) I*** 75. Select electrode placement sites. 76. Apply electrodes. 77. Set pulse rate. 78. Set pulse width. 79. Set intensity.	Relax condition A (adds steps 70-82, 100-108, 116-136 as substitute for 66-69), but include secondary condition R, Patient has had TENS before (cuts steps 70-74), secondary condition S, Patient does not tolerate noxious stim, (cuts steps 116-136), secondary condition T, Patient achieves satisfactory pain relief (deletes steps 80-82), and secondary condition U, no spasm associated with pain (deletes steps 100-108).
9	2	***TENS II*** 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 secondary condition R (adds steps 70-74).
		80. Adjust pulse width. 81. Adjust pulse rate. 82. Change electrode sites.	Relax secondary condition T (adds steps 80-82).
10	2	***Ultrasound*** 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 primary condition H (adds steps 83-91 as substitute for 70-82), but include secondary condition V, Part to be treated is not bony (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 secondary condition V (adds steps 86-88 as substitute for 83-84).
11	2	***Diathermy*** 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. 98. Set intensity.	Relax primary condition I (adds steps 92-99 as substitute for 86-91), but include secondary condition W, Patient is not obese (cuts step 99).
		99. Position applicator over area to be treated.	Relax secondary condition W (adds step 99 as substitute for 95).
12	2	***Ultrasound/Electrical Stimulation Combined*** 100. Position inactive electrode. 101. Set unit to US/E-Stim and 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 secondary condition U (adds steps 100-108 as substitute for 92-94 and 96-99).
13	2	***Laser*** 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 at remaining treatment points.	Relax primary condition G (adds steps 109-115 as substitute for 100-108).
14	3	***Neuroprobe*** 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 stim. 124. Rapidly increase intensity to patient's tolerance. 125. Repeat at remaining points.	Relax secondary condition S (adds steps 116-136 as substitute for 109-115), but include secondary condition X, Patient receives adequate pain relief with neuroprobe alone (cuts steps 126-136).
15	3	***Laser/Neuroprobe Combined*** 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 secondary condition X (adds steps 126-136 as substitute for 116-125).