Bridging the Gap between Research and Practice: Educational Psychology-Based Instructional Design for Developing Online Content

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I. Introduction

Associated with the increased occurrence of online courses in post-secondary education, are questions and criticisms about the design of online content and its bearing on learning. Curriculum developers are faced with making important decisions about the design of their learning materials. In some cases, media developers and instructional designers may also assist content developers, yet their suggestions may be grounded in issues of interface/graphical/technical design or a focus on learning activities. In other words, information about the effect of content presentation on learning may not be readily available. Many factors may affect the effectiveness of various instructional design techniques and a curriculum developer may be hard-pressed to find specific guidelines to assist them. Generally, instructional design texts tend to focus on broad areas such as writing learning objectives, designing activities and assessments, and perhaps general guidelines for message design (for an example, see Ledford & Sleeman, 2000; Kemp, Morrison & Ross, 1998). Meanwhile other resources focus on specific design issues such as how to use specific multimedia which may or may not be based on research findings. Even when research findings serve as the basis for instructional design techniques, resources may not take into account the effects of other implemented techniques which may impede, counteract or lead to a negative impact on learning.

Much relevant research is performed in educational psychology; some of which have focused on how content presentation impacts learning. Given that most if not all online courses contain content in the form of text, images, or multimedia, it is important for these research findings to be extracted at a broader level and employed in practical day-to-day tasks such as curriculum development. Applicable theories for content presentation and learning are dual-coding, cognitive overload, information delivery, cognitive theory of learning, cognitive theory of multimedia learning, and related concepts include prior knowledge, scaffolding, signalling, seductive details, intrinsic and extrinsic load.

A comprehensive review of research literature over a period of time can provide a rich and comprehensive set of guidelines. Furthermore, by reviewing a set of literature as a whole, one can not only extract specific conditions where techniques will or will not work, but also if the implementation of several techniques conflict with or cancel out the effects of one another. For example, is the normally effective use of highlighting cancelled out by the effects of seductive details and if so why? In addition to the general questions of why and how to use various techniques given the specific context and needs of the course developer, these types of relational considerations among instructional design considerations are important.
Therefore, the goals of this research are to 1. review, analyze, and synthesize theoretically-grounded educational psychology research over the past 30 years; 2. derive specific instructional design techniques and related conditions, and 3. map out the intricate relationships among these techniques; thereby, developing a guide for post-secondary course developers. By providing this perspective to practitioners (curriculum developers or instructional designers), they can make more informed decisions about developing instructionally sound materials.

For the purpose of this paper and presentation, select articles from the past five years are drawn upon to identify more recent research themes, current findings and relationships which can be applied to content development for learning. As well, the basis for more recent research is a culmination of past studies and findings in the field, so to some degree takes into account prior research not covered in this paper.

**Overview**

Much research over the past five years has focused on the cognitive processes associated with learning. Increased attention to this area has resulted in research directions aimed at delving deeper into the conditions and processes by which students learn. This increased focus on the “learner” has important implications on the selection, development and implementation of instructional content. Advances in computer-based learning environments which can provide unique learning opportunities (as compared to traditional learning environments) have generated considerable research as well.

To bridge the gap between research and practice through findings in educational psychology literature, I believe it is absolutely critical for instructional designers and instructors to first understand how learning may occur and why. Next, as much recent research suggests, we need to be aware of the importance of learner experience. These two components set the foundation for making sound decisions about instructional design from an educational psychology perspective. After gaining a basic understanding in these two areas, we can then attend to examples of specific types of content and thus, better understand their appropriateness and limitations. This train of thought provides the structure of this paper and select research is presented for support.

**II. The Theory: Cognitive Load Theory (CLT)**

Though there are many theories related to mental processes and learning, the majority of recent research has directly or indirectly substantiated the tenets of cognitive load theory. Cognitive load theory asserts that the limitations of working memory should be considered in instructional design. It is based on the assumption that a learner has limited processing capacity and proper allocation of mental resources is necessary. Otherwise, devoting mental resources to activities not directly related to schema construction and automation may inhibit one’s learning.

Learning consists of schema construction and automation. Schemas are *domain-specific knowledge structures* which categorize multiple elements of information as a single element and determine appropriate actions. Hierarchically organized, schemas reduce the load on working memory and enable people to hold a presumably unlimited number of elements of information.
in long-term memory. Changes to schemas also result in changes in problem-solving strategies. Specifically, novice learners tend to work backwards from a goal, using means-ends analysis and subgoaling. As schemas develop, learners shift to a strategy of working forward from the initial problem state to the goal. This is a less resource demanding, expert strategy. **Controlled** processing requires conscious effort and thus, working memory resources, while **automated** schemas allow us to efficiently deal with large amounts of information that could not possibly be processed by our limited working memory. Automation occurs when operating schemas is no longer controlled, in other words, no longer requires conscious effort and related working memory resources.

### 1. Cognitive Load

Cognitive load focuses on how working memory limitations help to determine what kinds of instruction are effective. It occurs when **schemas** are not in place or when schema operation is **controlled** rather than **automated**. To better understand how cognitive load occurs, a brief description of working memory is needed.

Working memory or cognitive capacity is the part of our cognitive architecture where active processing occurs. It is limited in capacity and its simultaneous limits are estimated to be seven chunks of information. In addition to storage, information processing is also limited. Working memory capacity may be limited to processing two or three chunks when there are multiple processing demands. Baddeley (1992) identified one central structure that controls information processing within working memory and two slave systems: visual and acoustic subsystems. Learning activities that minimize processing and/or storage that is not directly relevant for learning should be encouraged so as not to tax the limited capacity of working memory.

To explain instructional design considerations, recent research refers to cognitive load in varying depth. For our understanding, three types of cognitive load require review (Sweller, van Merrienboer, & Paas, 1998). **Intrinsic load** refers to the complexity of the learning material and number of elements a learner must attend to simultaneously in order to understand the learning material. The level of intrinsic load depends on a learner’s prior knowledge. High prior knowledge enables learners to construct larger meaningful chunks, thereby reducing cognitive load. A simple definition of intrinsic load is, “the complexity of the learning content relative to the learner’s level of prior knowledge”.

**Germane load** is comprised of the demands placed on working memory by mental activities directly associated with learning and should be fostered. For example, self-explanations, where the learner attempts to understand a solution rationale or a relation between concepts and automation of procedures, pose germane load in worked-out examples. A concise definition of germane load is, “efforts in working memory which contribute to the focus of the learning task.”

**Extraneous load** refers to mental activities during learning that do not contribute directly to learning. Similar to germane load, what constitutes extraneous load depends on the goal of the learning task. For example, when constructing problem-solving schemas is the goal, extraneous load results if instructional materials contain text and graphics that are difficult to integrate with each other. Learners may use much of their working memory to try to establish coherence between the two information sources. As a result, little or no cognitive capacity remains for
germane load, especially if there is also substantial intrinsic load because of the learning material itself.

*Redundancy effect* occurs when the removal of a redundant source of information enables limited mental resources to be directed to appropriate sources of information for schema construction and automation. It thus reduces the risk of *cognitive overload.*

### 2. Cognitive Skill Acquisition

Recent educational psychology research has focused primarily in structured domains likely due to complex challenges associated with defining learning processes in less structured domains. A goal of “learning” in structured domains is cognitive skill acquisition. As described by Renkl and Atkinson (2003), cognitive skills refer to the learners’ capabilities to solve problems from well-structured domains (math, medicine, electronics). It is a narrower term compared to “learning” and the cognitive aspects of skill acquisition are focused. The process by which cognitive skills are acquired is usually divided into several similar phases, though the specifics vary across theorists.

VanLehn’s (1996) model as described by Renkl and Atkinson (2003) dovetails with example-based process of skill acquisition (which are covered later in this paper). Three phases which correspond to those of other models are, the early, intermediate and late phases of cognitive skill acquisition. In the *early* stage, learners attempt to gain a foundational understanding of the domain without necessarily trying to apply the acquired knowledge. In this stage, learners study instructional materials that provide knowledge about principles in example-based skill acquisition process. In the *intermediate* stage, learners attend to solving problems and learning is focused on how abstract principles are used to solve concrete problems. Here is where flaws in one’s knowledge base are corrected. In the *late* stage, practice heightens speed and accuracy. Actual problem solving (as opposed to reflective considerations such as self explanations) occurs and is critical. The phases do not have precise boundaries and are multi-layered. For example, a student may enter the late stage of acquiring a skill in a subcomponent while still operating in the early or intermediate phase of acquiring skills in other subcomponents. Learners may be simultaneously in different stages with respect to different parts of a skill.

### 3. Cognitive Theory of Multimedia Learning

More recently, multimedia learning has become a focus of research. Building upon cognitive load theory above, Mayer and Moreno (2002) propose three premises about human cognition or thinking: We have two separate channels for processing visual/pictorial representations and auditory/verbal representations of information (the process of these two areas of working memory is otherwise known as the *dual-processing theory*). There is limited capacity for processing information. When learning, we actively process information by selecting, organizing and integrating material with existing knowledge. Given their extensive work in examining computer-based multimedia learning, they have coined the term *cognitive theory of multimedia learning.* This theory is based on cognitive research and assumes that presenting material in pictorial and verbal form concurrently makes use of both channels of working memory and, under certain conditions, will promote more meaningful learning than a single-mode presentation. Mayer has dubbed this the *multimedia principle* (Moreno & Mayer,
1999) and its implementation is otherwise known as dual-modality instruction. The key idea is for more meaningful and effective learning, multimedia that makes a coordinated use of our two separate verbal and visual processing (working memory) channels should be developed or selected. Details about different types of multimedia content follow in the section about content.

Kalyuga, Ayres, Chandler, and Sweller (2003) have further described split attention and redundancy effects. When two or more related sources of information are presented, learners may need to integrate mentally corresponding representations (verbal and pictorial) to develop a schema and understanding. However, split-source instructions are not recommended. They are separate information sources in space or time which may tax limited cognitive resources by causing the learner to focus on cross-referencing and search-and-match processes. This extraneous load may interfere with constructing integrating schemas, thereby burdening working memory and inhibiting learning.

Moreover, the authors recommend embedding text directly into a diagram and close to the related components in the diagram. The physical integration of representation formats prevent learners from splitting their attention, reduces visual search and decreases cognitive load. This is otherwise known as the split-attention effect. Another consideration is whether or not both sources of information are essential, in other words, unintelligible by itself. The redundancy effect postulates that if one source is unnecessary, then removing one is a better choice or else it is redundant and may result in inefficient use of working memory. For example, research has indicated that a diagram alone is better than a diagram with text that repeats the information in the diagram. Redundant visual and auditory text has been found to be less effective than auditory alone (Craig, Gholson, & Driscoll, 2002; Kalyuga, Chandler, & Sweller, 2000; Mayer, Heiser, & Lonn, 2001).

4. Theoretical Implications for Content Development

Cognitive Load Theory clearly suggests that attention needs to be paid to the effects of learning materials and instruction on cognitive processes. When designing content and activities, instructors need to consider the mental load the learning material poses (intrinsic load), the working memory resources needed in learning material or performing the learning task (germane load) and cognitive processing required for activities not related to learning (extraneous load). For example, though there may be a temptation to make “full use” a computer-based medium to deliver learning content and activities in a variety of ways, this will likely overwhelm learners and inhibit them from developing schemas for the domain, automation of schemas, and learning. On the flip-side, cognitive load theory suggests that a certain level of interactivity is needed with the learning material and learning activities by the learner. Thus, using computer environments as a text-repository with little or no related learning tasks may also thwart learning.

Much of the research associated with cognitive load theory has focused on structured domains such as mathematics and science, where processes and solutions are relatively established. Therefore the instructional design suggestions made in this paper apply to structured domains. A fundamental goal of learning is to acquire cognitive skills. Regardless of the medium for content presentation or learning activities (i.e. print or computer-based), instructional design requires careful consideration of where learners are at in regards to
acquiring cognitive skills (i.e. early, intermediate or late stages). Appropriate instruction should be designed.

The presence of two overlapping, yet independent working memory subsystems suggests formidable possibilities for multimedia learning, where learning material and instruction can be provided in both visual and auditory forms. Learning benefits have been found for various multimedia materials which make use of the two modalities. However, the cognitive theory of multimedia learning, cautions us to be aware that learners have limited capacity in working memory and suggests the coordinated use of our two subsystems.

**III. The Learner: Learner Experience**

Recent research has investigated interactions between levels of learning knowledge (experience) in a domain and levels of instructional guidance (e.g. worked examples and problems to solve). Current research recognizes the essential role learner characteristics play on learning and emphasizes the need to consider the learner’s experience or expertise in a domain when developing instruction. For example, attempts to reduce cognitive load by providing additional structure or guidance may actually increase cognitive load in complex tasks. Whether a task is complex or simple depends only partly on the structure of the tasks and depends on the level of learner experience (or expertise) in a domain (Kalyuga, Chandler, & Sweller, 2001). Furthermore, the information that is relevant to a learner and thus, attended to, depends on the learner’s level of expertise (Kalyuga, Ayres, Chandler & Sweller, 2003).

At some point, students may need supports or scaffolds to facilitate their learning. These supports may be found within activities such as authentic tasks where students are expected to learn by doing, or cognitive apprenticeship (Mayer, Mautone, & Prothero, 2002). Instructional materials may include authentic problems (e.g. in science) to be solved and tasks that are mainly visual in nature – i.e. solvable through viewing images, or interacting with an animated object or simulation. These resources may provide students with pictorial representations (pictorial scaffolding) of possibilities before they attempt the problems. However, while pictorial support may aid problem-solving performance, adding verbal statements about how to solve the problems (strategic scaffolding) may not have any effect for novice learners (Mayer, et al., 2002).

As students become more experienced in a domain, they may not need as much support and thus, more appropriate instruction is needed. For example, though presenting a diagram with narrated text has been found to be the most powerful of diagram-with-text combinations, Kalyuga, Chandler, and Sweller (2000) suggest that after learners become more experienced, the advantage of this form of presentation may disappear and attending to redundant explanations would be needlessly associating corresponding elements from the two modes of presentation. Kalyuga, Chandler, Tuovinen, and Sweller (2001) found that inexperienced learners benefited most from worked examples, while more experienced learners benefited from problem solving because worked examples became redundant. They suggest that the effectiveness of worked examples or problem solving depends on levels of learner knowledge (see section on examples for more details).
1. Cognitive Load Theory and the Learner

How does learner experience relate to learning? Cognitive load theory may provide plausible explanations. Differences in learners’ experience may be explained by a schema-based approach. Recall from the section above on theory, that novice learners aim to develop schemas, whereas experts already have a large number of domain-specific schemas which are hierarchically organized and allows experts to categorize multiple elements of related information into a single, higher level element. This element requires less working memory capacity. Automating schemas also help to reduce cognitive load.

Thus, the level of learner experience in a domain greatly influences which schemas can be utilized in working memory to organize presented information. Novices lack schemas and instructional guidance can substitute for missing schemas and help to construct them. If instruction does not present necessary guidance, novice learners resort to problem-solving search strategies which pose a heavy load on working memory. However, instruction presented to guide students may be redundant to an expert learner’s schema. Attending to both may cause cognitive overload for experienced learners and thus, have a negative effect on learning. A proposed solution is to remove instruction-based guidance for experienced learners (Kalyuga, et al., 2003). The individual differences principle suggests that instructional presentations should be designed to account for learner’s level of experience with more support for inexperienced learners’ cognitive processes than for experienced learners (Mayer, 2001). High level knowledge learners will use available prior knowledge (schemas) in learning activities where they are not provided specific instructional guidance.

Though considerable research has focused on the benefits of specific instructional content or techniques, apparently a large number of cognitive load theory (CLT) effects used to recommend instructional design are only applicable to learners with very limited experience (Kalyuga, et al., 2003). Benefits can disappear and then reverse for learners with more experience. In very recent research, Kalyuga, et al. have determined a reverse cognitive load effect where cognitive load effects reverse with expertise.

The authors describe interactions between levels of expertise (experience) and split-attention and redundancy effects. Learner expertise affects whether one information source should be eliminated or not. Novices may need redundant information, while a more experienced learner may not. Integrating several sources of information to decrease cognitive load for novices, for example, may not be effective with more experienced learners. The split-attention effect for novices may be replaced by the redundancy effect for experts. A very recent contribution to the understanding of learner experience is the notion of expertise reversal effect, where the positive effects of instructional guidance for novices becomes a negative effect for experienced learners (Kalyuga, et al., 2003). Instructional guidance becomes a burden on cognitive load by placing increased extraneous load on increasingly experienced learners who already have the understanding of the material being presented. Furthermore, an elimination effect occurs when a method is observed to benefit novice learners, but is less effective for more experienced learners – full reversal did not occur. A guidance-fading effect suggests providing a direct instructional application that coincides with the expertise reversal effect; specifically reduce guidance with increased expertise.
To summarize, inexperienced learners require instructional guidance to reduce cognitive load (especially for structurally complex instructional materials) and to help them develop schemas. Meanwhile, experienced learners who received instructional guidance undergo increased cognitive load because they try to integrate this new information with their existing schemas. So for experienced learners minimal instructional guidance is needed, which provides less cognitive load and prompts learners to rely on existing schemas. To address learners’ increased expertise over time, reduce instructional guidance with increased experience.

2. Learner Experience Implications for Content Development

This section presents a few key ideas to keep in mind when developing or selecting instructional materials. Most importantly, instructional design should be tailored to the level of experience of the intended learners. A significant challenge is to design instruction that allows changeable and adjustable levels of instructional procedures and techniques. Though initially time-consuming to map out, computer-based instruction has potential to help accomplish this. In a computer-based learning environment, the level of learner experience may also be identifiable more generally, such as through assessments, whether or not they have successfully accomplished various activities or are approaching a problem for the first time, or it may be implied because of the level of the material or course (i.e. introductory). Enable experienced students to skip or ignore redundant information (e.g. turn off auditory explanations). Some user control over multimedia so that students can work at their own pace are preferable. This may reduce an overload on their mental processing of information (cognitive overload). Students who are able to exercise control over their learning environment or materials may benefit in their learning. By working at their own pace students may be able to prevent cognitive overload and progressively build their understanding. For example, being able to control a part of a narrated animation on a scientific system prior to seeing the whole animation was found to help students to perform better on problem-solving transfer tasks (Mayer & Chandler, 2001).

IV. The Instruction and Content

Finally, now that we have a basic knowledge foundation about the cognitive processes of learning and the importance of learner experience, we can appreciate instructional and content-related recommendations derived from select educational psychology literature. The following section presents select findings from educational psychology research over the past five years. Three main categories of instructional techniques and materials are 1. problem solving, worked examples and problems, 2. textual content, and 3. multimedia. Ties to cognitive theory and learner experience considerations are included.

1. Problem Solving, Worked Examples and Problems

1.1 Problem Solving

Problem-solving, generating solutions to problems, or transferring knowledge about how to solve one problem to another is indicative of deep understanding and learning. There are many ways of solving problems and yet, it seems to be assumed that students know the appropriate strategies and how to use them. Little is known about students’ representations of problem-solving. Antonietti, Ignazi and Perego (2000) investigated students’ beliefs about problem-solving.
solving strategies. Undergraduates can differentiate the application of different strategies depending on the type of problem at hand and are able to identify relevant abilities for each method. However, there are some misconceptions about problem-solving techniques and their applicability to different types of problems.

When left to their own accord, students report using analogy as the most frequently used and easiest problem-solving method (Antonietti, Ignazi, & Perego, 2000). Analogy may be operationalized as finding connections between past situations in different areas and being able to transfer solution principles from one field to another, thus solving new problems. Step-by-step problem-solving and combining methods are deemed to be the most difficult. The latter is described as trying to associate or combine different aspects of the problem in order to generate new patterns or links towards a solution. A step-by-step method is a systematic search for a series of steps needed to progressively reach the solution and is believed to be the most relevant strategy for study problems; this method is least used for interpersonal problems mainly because these problems are viewed as holistic and not easily broken-down.

1.2 Worked Examples and Problems

We have all seen and learned through “examples” and “problems”. These are relatively general terms which have been applied to a wide range of instructional material. However in educational psychology, certain types of examples and problems are more clearly defined, have specific components or steps and are the target of much research, particularly a resurgence over the past five years. Research aims to identify conditions under which these instructional techniques are best applied.

Examples such as in story problems, may provide a context for students to see how certain steps are applied. Jonassen (2003) outlined a detailed review of story problems and proposed suggestions for designing instruction. To solve story problems, learners need to construct a conceptual model of the problem that combines the situational (story) content with an understanding of the nature of the problem based on principles in the domain being studied. The conceptual model also includes processing operations. Though story problems vary in situations, contexts, structural relationships between components within the problem, and processing operations, research indicates that learners must classify problems and construct a conceptual model of problems (prior to using formulas) in order to effectively solve story problems. The model requires: the structural relationships between aspects of the problem that define the class of the problem, situational details about the problem context, integration of the relationships and situational characteristics, and processing operations needed to solve the problem based on its structure. Constructing a conceptual model enables learners to classify problems before attempting solutions, a step necessary to transfer knowledge.

Worked examples are the key process to most story problem instruction (Jonassen, 2003). Worked examples (worked-out examples) provide a model for solving a specific type of problem and provides an expert’s solution step-by-step (Atkinson, 2002). They provide fully guided instruction which includes a problem statement and explanation of all solution details and are suitable in the initial acquisition of cognitive skills in well-structured domains such as mathematics, physics or programming and is effective for novices. (i.e. Renkl & Atkinson, 2003; Kalyuga, et. al., 2001; 2003). This helps students to develop the associations and relationships between information elements (develop a schema). Research suggests that worked examples might be more effective for simple tasks when learners select possible actions form a limited
number of options, and is thus, less cognitively demanding (Kalyuga, et al., 2001). The *worked examples effect* is the facilitation of learning through using worked examples and reduction in cognitive load. This happens because learners focus only on each problem state and its associated move.

An important observation made by Renkl and Atkinson (2003) about research and real-life application, is that in textbooks, usually a principle (rule or theorem) is introduced, followed by a worked-out example provided and then one or more to-be-solved problems are supplied. This procedure actually constitutes the control conditions (problem-solving only) of many problem-solving versus worked examples, studies. In other words, it may be assumed that studies on worked examples mirror the real life applications of worked examples, however this may not true. “Learning from worked examples” is different in that the “example phase” includes presenting a number of examples *before* learners engage in problem solving or examples are interspersed with the to-be-solved problems. Another misconception is that there is no problem solving in worked examples. Problem solving does occur, however it is delayed compared to traditional problem solving only procedures. In later stages of skill acquisition when performance and skills (or subcomponents) should become automated, learners need to solve problems. (Note. For a recent literature review about learning from examples and derived instructional principles from worked examples research, refer to Atkinson, Derry, Renkl & Wortham, 2000.)

**1.2.1 Worked-out Example Effect and its Reversal**

How do worked examples work? To start with, the level of learner expertise must be considered. The low level of prior knowledge at the beginning of a learning process raises two assumptions, 1. Learners are unable to apply domain or task-specific solution procedures, so general problem-solving strategies must be employed, and 2. there is high intrinsic load. At this point, *Problem-solving* imposes high extraneous load because a learner has to focus on following aspects of the problem: current problem state, goal state, differences between the two states, operators that reduce the differences between the goal state and the present state, and subgoals. Problem solving may be suitable in later phases of skill acquisition (see Kalyuga, et al., 2001 and 2003). *Worked-out examples* enable learners to concentrate on gaining understanding because they are not focused on performance and the different aspects of the problem. Past research has shown that learners do not actively self-explain solutions of worked examples and benefit from short training immediately preceding studying examples.

The advantage of worked examples fades over time, conversely learning by problem solving is found to be superior over time – thus a *reversal* of the worked example effect occurs across phases of skill acquisition. The *reversal effect* can be explained by the *redundancy effect*. Worked examples contain information that is easily determined by more experienced learners and are therefore redundant, which in turn takes away working memory which could be devoted to *germane load*. Redundant information becomes *extraneous load* and may interfere with constructing schemas by experienced learners. The *individual differences principle* (instruction should be designed to account for learner’s level of experience with support for inexperienced learners’ cognitive processes being greater than that provided for more experienced learners) is in accord with the *expertise reversal effect*. Worked examples provide support for cognitive processes for inexperienced learners, while they provide redundant support for experienced learners.
1.2.2 Fading Out

Cognitive research has shown that learning from worked examples is effective during the initial stages of cognitive skill acquisition while in later stages, solving problems is superior. In Renkl and Atkinson’s (2003) paper, they provide a theoretical analysis of different types of cognitive load and their changes over the stages of skill acquisition. They also propose a fading procedure in which problem solving elements are successively integrated into examples until learners are expected to solve problems on their own.

In the early stage of cognitive skills acquisition in worked-examples, learners study instructional materials that provide knowledge about principles in example-based skill acquisition process. In the intermediate stage, when learners attend to solving problems, Renkl and Atkinson (2003) suggest that students first study a sample of examples before turning to problem solving in this phase. To acquire sound knowledge, learners need to actively explain the solutions and reason about the rationale of the solutions; studying examples or problem solving alone does not produce a quasi-automatic attainment of sound knowledge. In the late stage, learners actively solve problems to develop speed and accuracy. In summary, cognitive load theory (CLT) provides a useful framework with respect to the changing status of examples-problems of phases of skill acquisition and structuring the transition from example-based learning in the early stages to problem solving in the later stages.

In an attempt to integrate Renkl and Atkinson’s (2003) ideas and cognitive load theory from a previous section, table 1 depicts learning by worked examples and problems by identifying the stages of cognitive skill acquisition, associated learning, type of cognitive load, and related instruction. The table suggests that goals need to be more defined than “schema construction” and “schema automation” (i.e. learning goals presently focused on in CLT). When instructional procedures are employed they should promote *germane load*. Furthermore merely reducing *extraneous* load (i.e. often the focus of CLT) is suboptimal. Attention is needed to promote germane load. The table also illustrates *fading out*.

*Fading out* (fading) proposes the gradual elimination of worked examples as learner knowledge increases and replacement by problems (Renkl, Atkinson, & Maier, 2000; Renkl & Atkinson, 2003). This is suggested to be better than an abrupt switch from worked examples to problems (Renkl, Atkinson, Maier, & Staley, 2002). This structured transition should occur between the intermediate to late stage skill acquisition with decreasing worked-out solution steps and increasing problems-to-be solved after a phase of example study. The positive effects of fading support the *expertise reversal effect*. 
Table 1: Mapping out learning with examples and problems.

<table>
<thead>
<tr>
<th>Experience</th>
<th>Early</th>
<th>Intermediate</th>
<th>Late</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning</td>
<td>Basic understanding</td>
<td>Start to solve problems (understand domain &amp; apply)</td>
<td>Actual problem solving; optimization (understanding acquired)</td>
</tr>
<tr>
<td>Task</td>
<td>Study materials</td>
<td>Use abstract principles to solve concrete problems</td>
<td>Practice (speed &amp; accuracy)</td>
</tr>
<tr>
<td>Approach</td>
<td>Worked examples</td>
<td>Worked examples for learners to actively self-explain/reflect. Move towards increased use of problems to solve to develop skill in this. Anticipating and imagining a previously learned solution path (introduction to problem-solving elements) for higher prior knowledge learners</td>
<td>Problem solving (reversed worked examples effect due to redundancy effect)</td>
</tr>
<tr>
<td>Skill</td>
<td>Gain basic understanding of domain</td>
<td>Develop ability to generalize over surface structures Proceed in skill acquisition</td>
<td>Automation of at least a subcomponent of skills (speed and accuracy)</td>
</tr>
<tr>
<td>Intrinsic load</td>
<td>The material being studied</td>
<td>Material being studied (gradual decrease in load as cognitive skill acquisition increases)</td>
<td>Material being studied (less load)</td>
</tr>
<tr>
<td>Germane load</td>
<td>Worked examples</td>
<td>Self-explanations (principle-based explanations, goal-operator relations, coherence among examples) Anticipating and imagining based on what has been learned to-date</td>
<td>Problem-solving</td>
</tr>
<tr>
<td>Extraneous load</td>
<td>Steps in problem solving</td>
<td>Steps in problem solving</td>
<td>Redundant information (examples) Self-explanations</td>
</tr>
<tr>
<td>Another approach</td>
<td>N/A</td>
<td>Fading worked-out solution steps:</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1. Present concrete example (model)</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>2. Present example where one single solution step is omitted (coached problem solving)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Increase the number of blanks step-by-step until only the to-be-solved problem remains (independent problem solving)</td>
<td></td>
</tr>
<tr>
<td>Cognitive load</td>
<td>N/A</td>
<td>Fading reduces heavy cognitive load and reduces errors in learning. By implementing a step-by-step approach, demands gradually increase.</td>
<td></td>
</tr>
<tr>
<td>Appropriate for</td>
<td>N/A</td>
<td>For problems solvable by applying specific “to-be-learned” rules (near-transfer) where reducing errors is advantageous</td>
<td>Fading can be used for problems that require modification of learned solution methods (far transfer). Though learned roles cannot be directly applied, errors may trigger reflection and deepen understanding of the domain.</td>
</tr>
</tbody>
</table>

1.2.3 Self-explanation Prompts and Imagination Effect

Research has demonstrated that successive fading out or removal of worked example solution steps help learners to transition from relying on examples to solving problems on their own. However, this has been found only to be reliable for near-transfer tasks, not for far-transfer tasks. Atkinson, Renkl, and Merrill (2003) combines fading with prompts designed to encourage learners to identify the underlying principles presented by each worked-out solution step. Benefits of this technique are found for both near and far transfer. The technique is recommended because it is relatively straightforward to implement, does not require additional time on task, and promotes both near- and far-transfer performance.
The self-explanation effect occurs when materials do not include reasons for missing steps. Learners who attempt to establish a reason for the steps by explaining the examples to themselves may lead to more learning than learners who do not. It is a dual-process where learners generate inferences and repairs are made to the learners’ own mental model. Self-explanation prompts may help to elicit principle-based explanations in the initial stages of learning, active processing and more deep understanding about the structure of the examples. It supports the cognitive apprenticeship model where learners work on problems with scaffolding provided by a mentor or instructor. Learners transition from example modelling to scaffolded problem solving and finally, to independent problem solving. Instructional scaffolding (through worked-out solution steps) is gradually faded. Furthermore, self-explanation supports reflection, also part of the cognitive apprenticeship process. Learners are prompted to reflect on their problem-solving process and determine improvements. Prompts encourage learners to determine the principle that underlies a solution step. Practical implications are that self-explanation, 1) produces medium to high effects on transfer performance, 2) effects are consistent across age levels, 3) does not interfere with fading, 4) easy to implement, and 5) requires no additional instructional time (just preparation!) They are suited for well-structured domains such as math and physics because the procedure is designed to elicit principle-based explanations (Atkinson, Renkl, & Merrill, 2003).

Another recently studied instructional effect that benefits more experienced learners is the imagination effect. This occurs when learners who are asked to imagine the content of instruction are found to learn more than learners simply asked to study the material (Cooper, Tindall-Ford, Chandler, & Sweller, 2001). Imagining is useful for more knowledgeable students who possessed appropriate pre-existing schemas, compared to worked examples, while the opposite occurred for less knowledgeable students (expertise reversal effect). It is closely associated with constructing and running mental representations in working memory which relies on having schemas to support this process. Otherwise, all relevant elements must be processed as individual elements, thus increasing cognitive load. Imagining may also increase the degree of automation of associated schemas, thereby improving performance. Therefore it is a recommended technique for more experienced learners.

1.3 Implications for Developing Content

Some key ideas from this section are that worked examples should be presented first. Then as learners become more familiar with a domain, problem solving can be used to further enhance and extend acquired skills. A fading out procedure can facilitate the transition between intermediate to late phases of cognitive skill acquisition. Design instruction that fosters productive self-explanation activities to ensure that the available cognitive capacity is used effectively; specific training in self-explanation may benefit learners. Findings on the use of self-explanation prompting in computer-based learning environments are mixed and require further research.

For optimal worked example and problem solving implementation, careful planning and design are needed, while keeping in mind the experience level of students. Worked examples learning can be used for simple tasks with inexperienced learners. For more complex tasks, implement worked examples first and when students are more experienced with the domain, exploratory learning can further enhance and extend acquired skills.
Presenting content online may provide unique options for students as their experience levels increase. As students start with worked examples and undergo performance tests, their scores and perhaps even subjective ratings of perceived load can be used to direct students towards problem solving or exploratory learning when appropriate. This can be done manually, where students are prompted for their scores and then asked to work through a different set of materials or automatically, where a system provides the appropriate instructional guidance. For example, a learning object might generate problems that illustrate specific strategies to approach problematic steps for a particular learner. The challenge is creating material to accommodate learner differences in experience.

Since worked examples are depictions of expert-thinking to solve a problem, multimedia can offer unique instructional materials such as a learning object where an expert thinks aloud as a problem is solved. Multimedia provides novel opportunities for aural and visual modeling of expert problem solving processes (Atkinson, et al., 2003).

2. Textual Content

2.1 Placement of Examples and Main Ideas in Text

Beishuizen, Asscher, Prinsen and Elshout-Mohr (2003)’s investigated the placement and presence of main ideas and examples in study text. The authors noted that expository text examples can be considered to be cognitive support in some cases, while in other cases be seen as seductive details. The ordering of examples and main ideas in text and effect on text comprehension has been controversial. The cognitivist view suggests that text comprehension is founded on main ideas, while constructivist view supports the use of examples. Beishuizen, et al.’s two studies examined the influence of main ideas and examples in study texts on text comprehension and also examined the effects based on Vermunt’s notion of concrete elaboration. Concrete elaboration occurs when learners relate course materials to concrete, known entities such as personal experiences, visual images, events, practical applications, etc. and is associated with deductive text comprehension.

General findings and suggested guidelines

1. Include examples in expository introductory texts. Examples function as cognitive supports for expository text comprehension as indicated through verbatim recognition and explanations of main ideas (sections without examples were poorly understood).
2. Avoid presenting irrelevant examples. Irrelevant examples diminish text comprehension of low concrete elaboration learners, perhaps because irrelevant examples contain seductive details and distract learners. Low concrete elaboration learners were found be sensitive to the presence of examples and benefit from relevant examples, which helped them to construct a concept by induction.
3. Present main ideas at the end of a section of text. This format appeared to support both low and high concretizing students, but in a different way. High concrete elaboration students appeared to be negatively affected by main ideas presented at the beginning of a section of text. The authors suggest that presenting a main idea too early, triggers learners to relate the idea to their own experiences and thus, deters learners from focusing on valuable information in the remainder of the text. Meanwhile, low concrete
elaboration students may use the main idea located at the end of a section of text to validate the concept they constructed while reading the examples.

Though some previous research has concluded that text comprehension and text searching skills are not related, interdependence has been found. Cataldo and Oakhill (2000) have also noted that more recent studies suggest that they are at last partially overlapping skills and their study supported this. Good comprehenders were found to be more efficient at finding specific pieces of information in a text than poor comprehenders. They also were better at remembering the order that specific words appeared in a text, which suggests better search strategies. However, the performance of good comprehenders was found to be similar to those of poor comprehenders when they had to search through scrambled text. This suggests that good comprehenders are guided to some extent by the representation of the content in a text and thus, text content should be carefully constructed to prevent negative effects on learner comprehension.

2.2 Text Cues

Information that is highlighted or cued within text, otherwise known as text signals can take the form of an overview, headings, or summary. Generally, organizational signals help students recall textual information. After providing students with a text describing an issue and various alternatives, Kardash and Noel (2000) found that that within a given piece of text, an overview of the text, use of headings and summary helped students to recall more topics and improved their overall recall of the information. A key idea is to include textual organizational signals such as overviews, headings and summaries to students to help them focus on important information.

Another area of research is text processing and the expertise reversal effect (Kalyuga, et al., 2003). Less experienced learners were found to benefit from additional explanatory material, while more knowledgeable learners were better able to process the material without additions. In these cases, cognitive load was reduced (as reported on self-reports on cognitive load). Text that is minimally coherent may be all that experienced learners need.

With so much information available lately, we may come across interesting bits of information and reason that providing this information in addition to main ideas would help students to be interested in the topic or find it more enjoyable. These are called seductive details and a rationale for their use is the increased interest in reading, causes the student to pay more attention and put more effort into learning the material. This is otherwise known as the emotional interest hypothesis (Mayer, Heiser, & Lonn, 2001). What impact do these details really have? Actually, seductive details have a neutral effect at best, depending on the type of text in which they are embedded. In some cases, they have been found to detract from learning required material. Also as we have gained from cognitive load theory, tasks or information not directly related to learning may result in extraneous cognitive load, thereby reducing necessary germane load.

2.3 Text and Pictures

Images with text may help students to learn more than text alone (Moreno & Mayer, 2002). Text illustration research occurred primarily in the 1970s and 80s. Carefully designed text
illustrations have been found to generally aid learners in a range of text-dependent cognitive outcomes (Carney & Levin, 2002). While research in the 1990’s continued to strongly support that claim, more recent research has come up with more details about conditions and variables related to picture facilitation. In addition, research has branched out to alternative media and technological formats (i.e. Mayer’s work). Based on a review of select recent research, Carney and Levin (2002) derived general guidelines for considering text-accompanying illustrations (see Table 2 for summary): suggestions which have “stood the test” for more than over a decade.

Table 2. Summary of Carney and Levin’s (2002) guidelines for illustrations which accompany text.

<table>
<thead>
<tr>
<th>Consideration</th>
<th>Guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content congruency</td>
<td>Select pictures that related to text content since learning benefits occur when pictures and text provide harmonious or supporting information.</td>
</tr>
<tr>
<td>Text complexity</td>
<td>- Avoid including pictures in texts that are highly concrete and engaging because they readily elicit visual images and are thus, learners are unlikely to benefit cognitively from additions.</td>
</tr>
<tr>
<td></td>
<td>- Generally, the more complex the text, the more likely pictures are helpful.</td>
</tr>
<tr>
<td></td>
<td>- Explanative (or interpretational) pictures serve as useful mental models if 1. the text describes a cause-and-effect system or complex process and 2. learners are novices in the domain.</td>
</tr>
<tr>
<td>Prerequisite skill</td>
<td>To benefit from the positive effects of pictures, students must have prerequisite basic reading skills. Students lacking these skills can improve their listening comprehension and recall through well-selected pictures.</td>
</tr>
<tr>
<td>Function</td>
<td>Keeping learning outcomes in mind, choose pictures based on their desired function in relation to the text: To “make the text more”: 1. more concrete (representational), 2. coherent (organizational), 3. comprehensible (coherent), or 4. codable/memorable (transformational).</td>
</tr>
<tr>
<td>Involvement</td>
<td>To maximize benefits from pictures as text accompaniments, design instruction so that students work with and think about the picture (i.e. label features, ask questions).</td>
</tr>
<tr>
<td>Proximity</td>
<td>Adjunct aids need to be near one another. Integrated or pop-up displays may be more effective than split displays where a picture and text appear in separated locations (picture-text adjacency principle).</td>
</tr>
<tr>
<td>Learning style</td>
<td>Consider students’ individual learning styles. For example, “imager” cognitive styles have been found to benefit more from animated pictures than students with “verbalizer” styles.</td>
</tr>
<tr>
<td>Pictures in textbooks</td>
<td>Pictures and illustrations in textbooks may or may not be designed to be cognitively useful. Even if they are, potential benefits occur only if learners perceive the illustrated content or process in the intended manner.</td>
</tr>
<tr>
<td>Mnemonic illustrations</td>
<td>Consider the use of mnemonic illustrations as adjunct aids to text. Advantages of these transformational pictures on learning have been found in many research studies.</td>
</tr>
</tbody>
</table>

2.3.1 Maps

Maps are another means of visually depicting information. To help learners recall geographical map features or to reconstruct a map later, the presence of borders may help learning. Borders help to close an image, resulting in an intact image that is associated with surrounding text (Verdi, Stamm, Johnson, & Jamison, 2001). This provides both a verbal (text) and visual (image) representation of the same information, the benefits of which were discussed earlier. Placing features near map edges rather than towards the middle may help students to recall features and reconstruct the map. Even when a map lacks a border, but features are located along the edge of the computer screen, students are able to remember just as much. The edge of the video display may serve as a border. Borders appear to define the parameters of content within a map and features close to borders are seen and remembered.
due to their association with the borders. Varying the colour of borders however, has no effect on learning. *When considering the use of maps:*

- Look for maps with borders to help students create an intact mental image.
- Look for maps with textual explanations near them to benefit from the two modes of presenting information (visual and verbal).
- Select maps with important features placed near border edges or the edge of a video display if your goal is for students to recall these features or reconstruct the map.

### 3. Multimedia

#### 3.1 General

Generally, students perform better when verbal input is provided aurally rather than visually. This is supported by Atkinson’s (2002) study where students who received visual examples and voice explanations reported less difficulty and performed better on solving word-problems than students who had visual examples and text explanations. For scientific or technical domains where systems or processes may be explained, a diagram with orally narrated text is the optimum way to present content when compared to a diagram alone, a diagram with visual text or a diagram with both visual and orally narrated text (Kalyuga, Chandler, & Sweller, 2000).

#### 3.2 Images and Animation

*Animation* is a “simulated motion picture depicting movement of drawn (or simulated objects)” (p. 88, Mayer & Moreno, 2002). Changes within an animation can highlight key components of a system, object or process and facilitate learning. Meanwhile, a static image is the least effective for learning while a static image with elements of a process or system illuminated by a colour change (sudden-onset) is more effective for recall, recognition, generating solutions and performance on explicit-deep knowledge questions (Craig, Gholson, & Driscoll, 2002). Key idea: *An animation or series of images where different elements of a system or object are highlighted may enable more effective learning than static images.*

#### 3.3 Animation and Narration

Computer-based learning materials may include a visual and auditory component such as animation and narration. As previously determined, the use of both existing channels for processing information (working memory) has positive effects. For example, compared to students who receive only text explanations, students instructed by an animated character with voice (narration) produce more conceptually accurate solutions on practice items and transfer problems, and report perceiving the examples as less difficult (Atkinson, 2002).

Several studies by Mayer (i.e., Mayer & Moreno, 2002, Mayer & Moreno’s work pre: 2000) demonstrated that animation facilitates students’ learning in scientific and mathematical domains when implemented in ways that are consistent with the *cognitive theory of multimedia learning*. Students studying a process through animations with a concurrent narration perform better in recall, matching and generating solutions to problems than students who receive
animation with concurrent on-screen text (Mayer & Moreno, 1998). Generally, students perform better when verbal input is provided aurally rather than visually. This is supported by Atkinson's (2002) study where students who received visual examples and voice explanations reported less difficulty and performed better on solving word-problems than students who had visual examples and text explanations.

Key ideas (which are particularly useful in the development of re-usable, instructionally sound learning objects):

- Learning materials that make use of both the visual and verbal channels of information processing (working memory) are more effective for learning than a single representation of information or multiple representations through the same modality.
- Design learning materials with animation and narration rather than narration alone. The multimedia then makes use of our visual and auditory subsystems.
- Animation and narration is a better combination than animation and on-screen text. Animation and text both require processing by the same mental process (visual channel) and may compete with one another, while animation and narration make use of both, auditory and visual subsystems.
- Animation and narration should be presented concurrently rather than consecutively so that students develop a stronger sense of the association between the information seen and heard.

3.4 Pedagogical Agents

Animated characters may be designed to guide students in their learning of the presented material. This use of pedagogical agents is relatively new and further studies are needed its effects on learning. However, Craig, Gholson, and Driscoll (2002) suggest that the presence of an agent who presents examples to students has no effect on retention, recognition, problem-solving or multiple-choice items and does not challenge the attention (split-attention effect) of learners. Furthermore, characters that gesture toward the material do not improve learning.

On the other hand, students’ learning is affected when presented with one of three types of characters: 1. a pedagogical agent with facial movement and who narrates, 2. an agent who has facial movement, narrates and has printed text appearing in a cartoon-like bubble that is in synch with the spoken narration, or 3. an agent with facial movement and printed text, but no narration. Students with an agent that narrates (with no additional text) may perform better on retention activities than print-only agents. These students also recognize information and generate better solutions to problems than students who receive either of the other two agents (Craig, et al., 2002).

These findings support Mayer’s extensive work which suggests that presenting the same information in both visual and auditory formats is redundant and may be less advantageous than narrated text alone. Animated characters to help guide students’ learning, called pedagogical agents, do not appear to have ill-effects on learning and may benefit students when both auditory and visual cues are provided and information is not redundant. However, pedagogical agents that provide redundant information within the same mode (auditory or visual) may negatively affect students by splitting their attention to focus on both sources of
Having only one source of information in each working memory channel is optimum.

### 3.5 When Less is More

A common perspective is that students will benefit from multiple forms of information to address individual differences or preferences in learning. This is known as the information delivery hypothesis which suggests that students learn more when there are multiple forms of delivering material because they can select the one that is best suited to them. While the previous sub-sections suggest ways for resources to combine multimedia for maximum effectiveness in learning, a general strategy is moderation since numerous studies have indicated when multimedia use becomes too much. Two different types of multimedia—one in each of the working memory channels are the optimum. Resources offering three modes of information reduce the effectiveness of learning.

For example, adding concurrent on-screen text summaries or text that duplicates narration has a negative effect on learning explanatory texts (texts that explain a process or system). Diagrams with both visual and narrated text also deter effective learning (Kalyuga, Chandler & Sweller, 2000). Mayer, Heiser, and Lonn (2001) found that students who received this addition while studying a passage describing the process of lightning, performed worse on retention and transfer tests than students who received only the animation and concurrent narration. Adding text on top of a narration and animation can hurt students regardless of whether the text is a summary or exact text of the narration. Students are overloaded in the visual working memory channel and perform poorly compared to the no-text group. Trying to reconcile the summary with the narration poses an increased load on mental processing (cognitive load) for learners (Mayer, Heiser, & Lonn, 2001). This also the case when diagrams are presented with redundant visual and narrated texts (Kalyuga et al., 2000).

This effect can be defined as a redundancy effect, where adding redundant on-screen text to a narrated animation diminishes the effectiveness of multimedia learning. Furthermore, the negative effect can also be explained by a split in students’ attention. The narration and text both require a student’s visual attention and compete for it, and the student cannot fully concentrate on either. This supports cognitive load theory which proposes that each of us has a limited capacity working memory that consists of semi-independent subcomponents to manage auditory or verbal information and visual 2- or 3-dimensional information. Furthermore, we have a fairly unlimited long-term memory that holds schemas that vary in their degree of automation (Sweller, van Merrienboer, & Paas, 1998). Recall that schemas organize elements of information and reduce working memory load by grouping information together as a single element rather than working memory having to process each element separately. Research on multiple modes of information presentation supports the cognitive theory of multimedia learning.

Key ideas:

- More ways of presenting the same information within a resource, is not necessarily better.
- For optimum multimedia use, select multimedia resources that have only one verbal and visual component (e.g. narration and animation).
• Resources that contain more than one type of information of the same mode (auditory or visual) are not recommended because students’ attention and processing of the information will be split between the two sources of information.

3.6 Sequencing

As indicated above, resources with redundancy in presenting content may be beneficial to learning as long as students are not required to split their attention within the same channel in working memory. Specifically, adding on-screen text to a narration may help students to retain information, transfer knowledge and problem-solving skills and match questions and answers on tests about scientific systems as long as graphics are not presented at the same time as the text (Moreno & Mayer, 2002). Students who view an animation prior to receiving an explanation (on-screen text and narration) may also benefit. In general, presenting redundant verbal information sequentially may help students develop a mental model.

As indicated in earlier sections, providing concurrent animation and narration benefits students’ learning and supports the dual-processing model of working memory.

3.7 Seductive Details in Multimedia

Seductive details (added “interesting” unimportant information that is related to the learning materials and thought to encourage learner interest in the topic) have a neutral effect at best, depending on the type of text in which they are embedded. However, what about other media? Unfortunately seductive details in narration or video clips have been found to have negative effects on students’ retention and transfer performance as well (Mayer, Heiser, & Lonn, 2001). Regardless of whether video clips containing seductive details are inserted within or before a presentation, they still deter from learning and knowledge transfer. As suggested in the previous section for explanatory texts, seductive details at the beginning of course material may call up inappropriate prior knowledge which then sets up an incorrect schema for learning. This is the case even when seductive details are topically relevant, but not conceptually or structurally relevant in explanatory passages; in other words, they are related to the topic, but do not explain anything about the topic’s process or structure.

Employing interesting video clips does not support the emotional interest hypothesis because even though students’ attention is peaked at the beginning of the presentation by the video clips, they do not remember any more than those who received the video clips after. In addition, problem-solving transfer is worse when irrelevant information is presented at the beginning rather than at the end of material (Mayer, Heiser, & Lonn, 2001). Lastly, what about resources that contain music or sounds? Might those keep students interested in the content? By definition, those types of add-ons are not seductive details per se because they are not always, “related but unimportant information.”

We might think that resources with interesting material will increase students’ enjoyment of the material, and result in the student giving more attention to and applying more effort in learning the material (emotional interest hypothesis). Similarly, entertaining auditory elements may make learning more interesting, resulting in better attention and processing of material and finally, improve performance (arousal theory) (Moreno & Mayer, 2000a). In both cases it appears to depend on the situation. For example, employing seductive details in either text or
multimedia resources with the hopes of increasing student interest, effort and engagement may be detrimental to students’ problem-solving and transfer of problem-solving skills.

In addition, research suggests that unnecessary auditory material or that which is not integrated with the learning material can overload the student, specifically his or her auditory working memory and thus negatively affect learning (Moreno & Mayer, 2000a). Presenting music with the learning environment causes students to remember less material and solve fewer problems on transfer tests. The combined effect of having both music and environmental sounds is the most detrimental, while environmental sounds alone do not appear to have any effect. This is the case for scientific or cause-and-effect material. Relevant environmental sounds do not harm learning when they are integrated with the learning material. However, for environmental sounds to benefit learning, the optimum level of informational content for these sounds has yet to be determined (Moreno & Mayer, 2000a; Moreno & Mayer, 2002).

Key ideas:

- **Seductive details** are interesting, yet unimportant bits of information embedded within an instructional resource. In other words, the information is not related to the main ideas you are trying to convey to your students.
- The idea that seductive details spark interest and foster learning has not been supported.
- Seductive details in multimedia such as video clips may interfere with learning and recall of main ideas.
- If seductive details cannot be avoided (i.e. learning materials already include them), try not to use multimedia resources that contain seductive details at the beginning of the presentation where its effects are the most persistent and students may be deterred from recognizing and learning main ideas.
- For optimal learning, design or select materials that do not contain extraneous words, sounds (including music), and video which can distract students.
- Upon finding a visually-based authentic problem for learners, see if it also has visual supports or **scaffolding** to help them focus on possibilities for solving the problem prior to their attempt.
- Resources that are visually-based authentic problems may include verbal scaffolding such as information about strategies for solving the problem. These are generally not as effective.

**Conclusion**

The general implications of this paper are two-fold. First, recent research highlights the need for instructional designers to consider the cognitive processes associated with learning. Specifically, that learners have limited working memory capacity (cognitive load) and instructional materials should be developed to maximize the focus on instructional activities (germane load), while keeping in mind the mental effort necessary for working through the instructional material (intrinsic load) and minimizing learners’ attention to activities and materials not directly related to learning (extraneous load). Secondly, the extent to which the various types of cognitive load come into play with selected instructional materials, is dependent upon learner characteristics such as learner experience (or expertise) in a given
domain. With these two considerations in mind, instructional designers can then select specific instructional guidance and content components which best promote learning for their students.

As indicated earlier, the scope of this paper has been limited the select research trends and findings from the past five years. The forthcoming presentation provides an overview of theory, followed by findings associated with learner characteristics and conclude with highlights of specific instructional materials which are based on the previous two areas. Relationships between theory, learner experience and instructional content and direction are examined.
References


