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Insights from Educational Psychology Part 9: Planning Instruction

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Insights from Educational Psychology Part 9: Instructional Design

The first four columns in our series on insights from educational psychology for academic librarians focused on individuals' interests, motivations, intellectual development, self-concepts and emotions. Columns five through eight had a general theme of social aspects of learning, including diversity and inclusion, extrinsic motivators, and academic help-seeking behaviors. The final third of this series of columns will apply the principles we have outlined thus far to the topics of lesson planning and instructional design, teacher behaviors and assessment, learning strategies, and interventions to modify attitudes and behaviors.

In this column we will describe insights from educational psychology for designing instruction and planning lessons. We will only briefly summarize a few of the most widely used models for instructional design, and refer readers to the recommended readings for more detailed guidance. Special attention will be given the educational psychology research on motivation, cognitive load, problem-based learning, inquiry learning, worked examples, and scaffolding.

Principles of instructional design

The fundamental difference between lesson planning and instructional design is that a lesson plan applies known solutions to the problem of how to get students to achieve learning outcomes, whereas design is about choosing among alternative strategies to apply effective modes of instruction. The gist of instructional design is quite easy to describe but vexingly difficult to implement well. Put simply, one decides what students should learn, chooses how to assess the degree to which students have achieved the learning outcomes, then plans the activities most appropriate to achieve those goals. The basic premise is to work backward from measurable learning outcomes to plan lessons, assignments, or whatever else suitably leads students to achieve the learning objectives. The vexing difficulty lies partly in the challenge of choosing among myriad possible forms of instruction, but more so in the inevitably wide range of students' abilities and interests. Effective instructional design is about matching activities to best meet the needs of individual students, while keeping a clear focus on the desired learning outcomes.

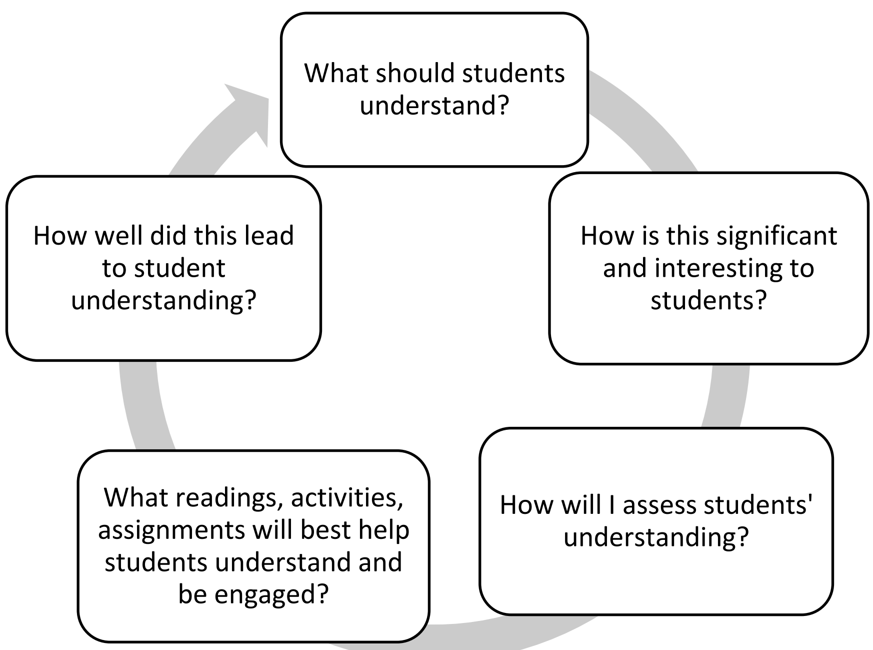
The idea of instructional design is hardly new. Glaser (1976) argued that educators should test teaching alternatives in an iterative process to discover the most effective methods to meet the needs of individual learners. Bloom's (1976) work on mastery learning also put major emphasis on individual students' abilities and motivations. He asserted that almost any student can achieve desired learning outcomes if provided appropriate instruction (Bloom, 1976). Appropriate design requires determining students' aptitudes, defining the learning outcomes, and planning instruction based on the aptitudes and goals. Well-designed instruction that is attentive to individuals' needs creates a positive learning environment (Allen, 1986).

A major challenge for librarians is how to design instruction when we often have little or no role in setting course learning objectives or creating assignments. To be truly effective in our instruction, it is essential to collaborate with professors to agree on learning objectives and appropriate means to help students achieve them. Although the desired level of collaboration is not always feasible, a librarian with solid knowledge of the principles of instructional design is more likely to be perceived by professors as a valuable collaborator rather than simply a service provider.

Wiggins and McTighe (2006) assert that instructors' fundamental goal should be to answer the question "How do we make it more likely—by our design—that more students really understand what they are asked to learn" (p. 4). Achieving that goal requires clearly expressing what students should understand, determining what evidence the students will provide to demonstrate understanding, and creating and delivering activities and assignments that lead students to understand. Understandings can be of the big picture or of specific concepts, and teaching typically involves a mix of broad and specific learning goals. Wiggins & McTighe (2006) describe six ways people express understanding: “can explain, can interpret, can apply, have perspective, can empathize and have self-knowledge” (p.84). Good instructional design will include clear expressions of not only what is to be understood but also what type(s) of understanding will be expressed and assessed. An example is Goben & Nelson's (2018) application of *Understanding by Design* (Wiggins & McTighe, 2006) to their development and implementation of the ACRL Research Data Management RoadShow.

There are several models for instructional design, but they all share the fundamental idea of designing backward from clearly stated learning goals and determining how they are to be assessed. A generic representation of the basic elements of instructional design is depicted in Figure 1 [insert Figure 1].

Figure 1: Essence of Instructional Design



According to (Fink, 2013), backward design should focus squarely on creating significant learning experiences for students. Significant learning blends foundational knowledge, ability to apply knowledge to novel situations, integration of learning across life experiences, self-knowledge and understanding of others, developing values and empathy, and learning how to learn (Fink, 2013).

One of the best known models for design thinking is ADDIE: Analyze, Design, Develop, Implement, Evaluate (Booth, 2011). The ADDIE design cycle can be applied to any creative endeavor, but here we will focus on its application to instructional design. The cycle begins with analyzing the needs and characteristics of the audience and determining learning goals. Next one designs an instructional strategy that matches needs and goals, then fleshes it out by developing activities and assignments. Implementation over the given time frame is followed by evaluation of the design's effectiveness.

As librarians, unless we are teaching an information literacy course for credit, we are very unlikely to be much involved in the design of assignments for understanding, significant learning, or development and analysis. Instead, we typically work to help students develop the skills they need to complete assignments that may or may not be well designed. So when we plan backward, it's usually backward from the instructor's assignment. What we can do in the short run is try our best to thoroughly understand the instructor's goals and match our teaching to maximize students' ability to achieve those goals. We may also be able to design our instruction to include significant information literacy learning goals that have not been explicitly requested by the instructor. In the longer run, if reference and instruction librarians learn and practice the principles espoused in well-respected guides such as *Understanding by Design* (Wiggins &

McTighe, 2006) and *Creating Significant Learning Experiences* (Fink, 2013), we may come to be recognized as valuable campus collaborators. If we can demonstrated expertise in instructional design within the context of using library resources, professors will have good cause to ask for our advice on choosing learning goals and planning assignments.

Designing instruction to motivate students

Readers may recall in Part 7 of this series on extrinsic motivation we described and cited research that suggests the best mix of motivators is moderate external motivation (e.g. concern to make a good grade) and high internal motivation (Black & Allen, 2018). We would all like students to be intrinsically motivated to use library resources efficiently and effectively. But all too often some blend of extrinsic motivators need to be offered students to get their attention and spur their interest. Keller (2009) argues that instructors should make it their job to include motivation techniques in instructional design, with specific focus on Attention, Relevance, Confidence, and Satisfaction, aka the ARCS model. Attention is gained through finding ways to make instruction stimulating and interesting. Relevance is achieved by determining how the learning experience will be valuable for students. Confidence comes from including support to assure student success. Satisfaction comes from designing instruction to help students have positive feelings about their experience and thus desire to learn more.

Even in one-shot instruction sessions, paying attention to the ARCS model in the context of what skills and concepts need to be covered can be a useful design tool. Hess (2015) provided an overview ways librarians have applied the ARCS model to information literacy instruction and advocated for further research on how to incorporate motivation into librarians' planning for instruction. She notes that the dispositions included in the *ACRL Framework for Information*

Literacy for Higher Education implicitly call for motivational design in information literacy instruction (Hess, 2015).

In our experience, there is a powerful tendency for professors to expect librarian's role in the classroom to be to introduce basic concepts and skills. Based on what educational psychologists have learned about interest, motivation, and instructional design, that emphasis on covering basics may be misguided. The common but rather vague goal many professors have of "students will learn to use the library" might be less educationally effective than "students will learn the value of librarians as resources for their research." The second goal may be better met by introducing students to advanced tools and techniques and building rapport rather than devoting the session to teaching basics.

Content vs. process and cognitive load theory

A common theme in the instructional design literature is the need to appropriately balance coverage of disciplinary content with learning processes and procedures. Opinions among professors on the proper balance of content and process vary considerably, and we have heard very strongly held and vehemently expressed views among peers throughout our careers in higher education. Among educational psychologists, a key factor in how much content to cover is cognitive load. "The basic idea of cognitive load theory is that cognitive capacity is limited, so that if a learning task requires too much capacity, learning will be hampered" (de Jong, 2010, p.105). Working memory is taxed during learning in three ways: intrinsic cognitive load, extraneous cognitive load, and germane cognitive load (de Jong, 2010). A summary of the three types of cognitive load and their implications for instructional design are summarized in Figure 2 [insert figure 2].

Figure 2: Why students don't ask for help

GOALS AND MOTIVATIONS
Fatalist attitude
Lack of motivation to complete task
Unwilling or unable to devote time and effort
Concern for social status
SOCIAL INTERACTIONS
Peer influence and group dynamics
Inability to articulate why they are asking for help
Preservation of self-image and self-esteem
Perceive potential help provider as not the relevant person to ask
Desire to avoid being a burden
PERSONAL CHARACTERISTICS
Desire for autonomy and self-reliance
Fear help provider will lack empathy or ability to understand the situation
Discomfort with disclosing information about oneself
Overconfidence
LEARNING ENVIRONMENT
Lack of opportunity to ask for help
Lack of awareness of available help
Fear of negative consequences of revealing need for help
Past negative experiences

Intrinsic cognitive load is the perceived difficulty of the material being learned. Among cognitive load theorists, intrinsic load is generally considered to be out of the control of instructors due to the nature of what is being taught. In contrast to that view, proponents of differentiated instruction and Universal Design for Learning note that intrinsic load is very much controllable by the instructor. We will present that perspective in the last section of this column.

The most obvious contribution to instructional design from the research on cognitive load is the replicated evidence that minimizing extraneous load is essential to well-designed instruction. Backward design needs to include close attention to the degree to which each reading, activity, presentation, or assignment is well organized and relevant to the learning goals.

Unfortunately organization is not always within the control of an instructor, for instance when a database students must use has a confusing interface. Germane cognitive load is caused by the construction and use of schemas. Since construction of schemas is a main goal of learning, germane cognitive load is a good thing (de Jong, 2010). One must just be sensitive to how much interpreting, exemplifying, differentiating, and so forth students can handle at once, and appropriate scaffolding should be incorporated into the instructional design. The timing and pacing of new information is also important to avoid excessive cognitive load.

Tools that help students visualize interrelationships among concepts can facilitate the construction of schema. A schema is "a collection of basic knowledge about a concept or entity that serves as a guide to perception, interpretation, imagination, or problem solving" (VandenBos & American Psychological Association, 2015, p. 937). Educational psychologist have repeatedly confirmed that possessing applicable schema in long-term memory is fundamental to expertise (Kirschner, Sweller, & Clark, 2006). Figure 3 is an example of a simple graphic organizer designed to help students create a schematic model of how to formulate a search strategy [insert Figure 3].

Figure 3: A Simple Graphic Organizer

Search Strategy Worksheet

1. Write your research topic as a question:

2. What are the key words?		

3. What are related words for the key words?		
4. What subject headings (descriptors) match these key words?		

Kapur (2016) argues that an instructional design that allows students to first fail, and then learn from their mistakes, can be very productive. In his proposed model of productive failure, the teacher first asks students come up with solutions to a novel problem, immediately followed by instruction on expert ways to solve the problem (Kapur, 2016). While it might seem to make more sense to give the instruction first and then present a problem to be solved, making predictions (Kornell, Hays, & Bjork, 2009) and inducing a degree of confusion (D'Mello, Lehman, Pekrun, & Graesser, 2014) have both been shown to stimulate learning. The productive failure model is an interesting way to incorporate cognitive load theory and students' prior knowledge into instructional design. "Productive failure presents a way of first engaging students in unguided problem solving to elicit what students know, especially in the failure to solve the problem, and then using this information to consolidate and assemble new knowledge" (Kapur, 2016, p. 297).

Worked Example Effect

Sweller (1989) has argued persuasively that providing worked examples are an effective way to minimize negative effects of cognitive load. In a worked example, each step in a problem is demonstrated, and the learner does not have to choose among goals or search among alternatives. Multiple studies have shown that students who study worked examples solve test problems effectively than students taught by working problems out themselves (Rourke & Sweller, 2009) For example, Sweller (1989) found that algebra students who studied worked examples performed better than students who figured out on their own how to solve the problems, as counterintuitive result caused by reduction in cognitive load. The worked example effect has mostly been applied to well-defined problems in mathematics and science, but it has also been found to be applicable to ill-defined problems such as choosing appropriate search terms (Kickham-Samy, 2013) and applying visual literacy to identify design styles (Rourke & Sweller, 2009). One-shot library instruction sessions can be designed to take advantage of this positive worked example effect by demonstrating the process of conducting a search and articulating the thought processes that go into that search. If we accept Rourke & Sweller's (2009) conclusions, following the worked examples can be as effective as working through searches on one's own, at least for students who do not yet possess expertise.

Despite evidence for their educational effectiveness, worked examples do have limitations. They are not effective if students have to split their attention among examples, if the examples are redundant, or if the students already possess sufficient expertise to solve a problem on their own (Kickham-Samy, 2013). Based on their review of the literature on worked examples, Chun-Yi Shen & Hui-Chun Tsai (2009) make these recommendations for incorporating worked examples:

- Use incompletely worked examples to help the transition to independent problem solving

- Successively integrate elements of problem solving into a series of worked examples, with careful attention to pacing
- Break the overall learning goal into subgoals and design a module of instruction for each
- Integrate content so students do not have to split their attention between content (e.g. text and image on different pages or screens)
- Integrate both visual and auditory content into instruction
- Prompt students to explain what is occurring in the worked example.

Problem-based, discovery, and inquiry learning

Constructivism is based on the premise that learning is an active sense making process in which individuals construct knowledge from what they experience (Mayer, 2004). Constructivist methods of instruction often include opportunities for students to explore on their own, which in its various forms is often labeled discovery or inquiry learning. Problem-based learning is focused, experiential learning organized around the investigation, explanation, and resolution of meaningful problems (Hmelo-Silver, 2004). It has been used most extensively in medical education but is a common teaching technique in science and mathematics. Case-based learning is intended to bridge theory and practice by having students actively explore solutions to authentic tasks in cooperation with peers and with coaching from the instructor (Baeten, Dochy, & Struyven, 2013). The case method of teaching was pioneered in business education but is widely applied in the social sciences.

In its most extreme form, discovery based learning leaves students free to explore on their own with minimal guidance. Mayer (2004) summarized the results of three major studies to argue that pure hands-on activity without guidance and clear educational goals does not work.

Alfieri, Brooks, Aldrich, & Tenenbaum's (2011) meta-analysis concludes that unassisted discovery is ineffective, but discovery learning is beneficial for students if the process is supported by feedback, worked examples, scaffolding, and explanations. Novices do not have the experience and subject knowledge necessary to appropriately apply the methods of a discipline. “The practice of a profession is not the same as learning to practice the profession” (Kirschner et al., 2006, p.83). Krahenbuhl (2016) argues that in addition to insufficient knowledge, novices are hampered by limited working memory and the risk that whatever meaning they construct from inquiry learning may not correspond with reality. Hmelo-Silver, Duncan, & Chinn (2007) have responded to this critique by asserting it is a mistake to conflate inquiry and problem-based learning with unguided discovery learning. They argue that problem-based and inquiry learning are powerful teaching methods when designed with appropriate opportunities to learn applicable concepts and delivered with ample support for students who need guidance (Hmelo-Silver et al., 2007). One way to provide support is to begin with direct instruction (e.g. lecturing or assigning a reading) and then phase in independent problem solving as students build foundational knowledge (Baeten et al., 2013).

A key to the success of problem-based or inquiry learning is its potential to engage students to take an active role in their learning. Chi & Wylie (2014) describe an ICAP framework for linking engagement with learning goals at four levels of engagement: Interactive, Constructive, Active, and Passive. In their ICAP model, degrees of engagement are independent of the mode of instruction. For example, a student at a lecture may simply listen (passive), mentally repeat the content or take notes (active), ask questions or draw a concept map of what is heard (constructive), or follow the presentation with discussion or argumentation with others (interactive). Chi & Wylie (2014) argue that interactive engagement is the most effective form of learning and therefore should be incorporated into instructional designs. Constructive engagement is better for learning than active engagement, which is in turn better than being passive. They theorize that although interactive engagement entails a heavy cognitive load, the benefits of asking questions of a partner or debating points of view make the effort educationally beneficial (Chi & Wylie, 2014).

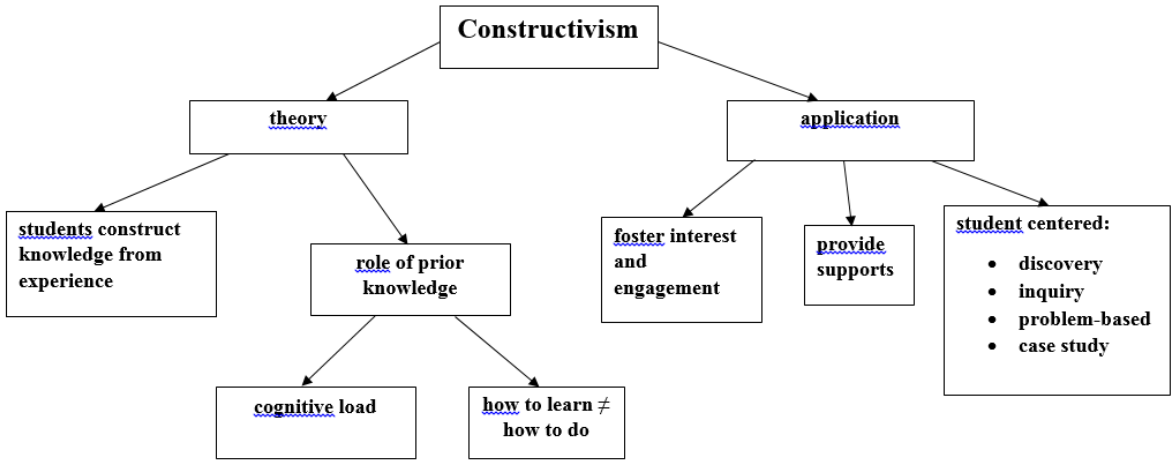
Scaffolding

What is quite clear from the literature is one cannot simply turn students loose and expect them to succeed without support. Not every assignment that requires research in an academic library qualifies as problem-based or inquiry learning, but many do. Experienced reference librarians are quite familiar with examples of students who lack the knowledge and experience to complete research assignment on an ill-defined problems on their own. We are not aware of any specific mention of reference librarians in the educational psychology literature on scaffolding techniques, but that’s essentially what we do. Scaffolding is defined as support provided by a teacher or other knowledgeable person that enables students to perform tasks they cannot presently perform independently (Wood, Bruner, & Ross, 1976). A properly conducted reference interview models good scaffolding.

The methods of support that have been described in the literature can enrich our practice as academic reference and instruction librarians. Mayer (2004) argues forcefully for the superiority of guided learning, and librarians are well positioned to be effective guides. Recognized effective scaffolding techniques that we can employ include coaching, giving hints, and recommending ways of structuring the research process. Puntambekar & Hübscher (2005) describe how the interactive nature of a transaction allows the teacher, tutor or librarian to conduct ongoing assessment of the student’s understanding, and the student comes away not only with ability to complete a task but also an understanding of how to conduct the process themselves.

Belland, Glazewski, & Richardson (2008) note that students usually need scaffolding to learn how to make evidence-based arguments and solve ill-defined problems (i.e. with no one right answer that can be looked up somewhere), describe three effective types of support: question prompts, expert modeling, and concept mapping. Question prompts get students to reflect on what they are learning, for example by asking a student “How will the article you found help you support your thesis” or “How do you know this is from a reliable source?” The reciprocal questioning technique has been found to be an effective type of prompt to get students to elaborate and reflect (King, 2002). A good example of expert modeling is a librarian demonstrating to an individual or class how to conduct a search or navigate a database. The search strategy worksheet depicted in Figure 2 could be considered both a form of expert modeling and a question prompt. A concept map is a method of organizing the elements of a problem into a system model (Jonassen, 2003). Figure 4 presents a basic concept map designed to support the reader’s construction of a mental schema of the ideas presented in this column [insert Figure 4].

Figure 4: Concept Map



Matching instruction to individuals' needs

As we noted at the top of this column, one of the great challenges of good instructional design is aligning learning goals to students' diverse interests, motivations, skills, and prior knowledge. We presented relevant findings from educational psychology on addressing diversity in Insights from Educational Psychology Part 6: Diversity and Inclusion (Black, Krahmer, & Allen, 2018), so will only briefly note again here two of the most relevant approaches. The first approach worth highlighting is Tomlinson's (2005) *The Differentiated Classroom*, which makes student differences integral to instructional design. Among the principles are incorporating ongoing formative assessments, measuring success by personal progress rather than achievement of a single metric of success, and giving assignments that provide students multiple options (Tomlinson, 2005). Multiple options are an important element in the second approach we highlight here, Universal Design for Learning (UDL) (CAST, 2017). UDL was developed from the realization that multiple modes of representing information help not only individuals with disabilities but can also boost learning by people without disabilities. We refer you to the CAST website http://www.udl.org for their valuable explanation of principles and tools for implementing UDL.

Kapur's (2016) productive failure model noted above is a good example of planning for flexibility and multiple modes of instruction, particularly the idea of using unguided problem solving to gauge students' prior knowledge and inform the content and modes of subsequent instruction. Reference librarians are quite familiar with matching instruction to individual needs, as noted in the *RUSA Guidelines* e.g. "identifies the goals or objectives of the patron's research, when appropriate (3.1.4)" and finds out what the patron has already tried, and encourages the patron to contribute his/her ideas (4.1.1)" (RUSA, 2008). The principles of differentiated instruction and Universal Design for Learning are valuable for the design of all forms of library instruction.

Takeaways for Librarians

- Plan instruction by first deciding what students should learn and understand, then determining how to measure how well the learning goals are met.
- Once goals and means of measurement are selected, design activities best suited to help students meet goals in formats that allow learning to be assessed.
- When designing instruction, ask yourself "How can this be significant to students' overall education and personal development?"
- Take time to reflect on what did and did not work well, and take notes for future planning.

- Librarians with a solid background in instructional design can be valuable collaborators with faculty.
- Question whether going over basics of how to use the library meets the most important goals of library instruction.
- Be aware of the cognitive load on students. Define terms, sequence from simple to complex, provide examples, minimize redundancy, and integrate material so students' attention is not split.
- Working through an example search can be more effective than having students work through a search on their own, especially if the students are novices.
- Having students try and fail can be an effective teaching technique if failure is immediately followed by instruction and opportunity to try again.
- Integrate visual and auditory information in instruction.
- Provide supports for students such as question prompts, modeling, and concept maps.
- Do ongoing assessment of students' learning and adjust instruction accordingly.
- Give students multiple ways to achieve the learning goal.

Recommended Readings

Booth, C. (2011). ***Reflective teaching, effective learning: instructional literacy for library educators*****. Chicago: American Library Association.**

Char Booth's excellent guide to the basics of high quality instruction deserves its role as a primary text for all instruction librarians. At its core is the USER method: Understand, Structure, Engage, and Reflect. Understanding the learning scenario includes analyzing the learners, the content, the context, and the teacher-librarian's strengths and weaknesses. Booth's summaries of learning theory are succinct and well expressed. Chapters on teaching technologies and instructional design provide useful outlines of the range of options librarians may apply to instruction.

CAST: UDL & the Learning Brain. (2018). Retrieved June 28, 2018, from http://www.cast.org/our-work/publications/2018/udl-learning-brain-neuroscience.html

The Center for Applied Special Technology (CAST) began in 1984 for the purpose of exploring how computer technology could enhance learning for students with learning disabilities. The group realized that methods to help special needs students had broader applicability, which led to their development of Universal Design for Learning. The web site is a rich resource of information about how to design instruction to meet the needs of diverse audiences. The main principle is to provide students multiple means of engagement, representation, and expression.

Chi, M. T. H., & Wylie, R. (2014). The ICAP Framework: Linking Cognitive Engagement to Active Learning Outcomes. *Educational Psychologist*, *49*(4), 219–243. https://doi.org/10.1080/00461520.2014.965823

The authors hypothesize that learning outcomes are the result of the degree to which students are engaged, on a heirarchical continuum of Interactive, Constructive, Active, and Passive. Passive learning involved simply storing information without integrating with prior knowledge. Active learning involves assimilating new information with what is already known. Students engaged in constructive learning activities generate inferences, elaborate, and are able to transfer what they have learned. Interactive learning extends constructive learning through dialogue with others, so they each learn more than could be accomplished individually. The authors compare and contrast the ICAP hypothesis with Bloom's taxonomy, noting that ICAP focuses more on the means of learning versus Bloom's focus on measurable learning outcomes.

Fink, L. D. (2013). ***Creating significant learning experiences: an integrated approach to designing college courses*** **(Rev. and updated edition). San Francisco: Jossey-Bass.**

L. Dee Fink works from the premise that the educational experience should significantly impact students' lives. Such significance has six components: foundational knowledge, application, integration, the human dimension, caring, and learning how to learn. Instructional design should address and integrate all six elements. The book includes examples from various disciplines. A major theme is the need to design a course in an integrated way, working backward from the overall goals to design activities best able to result in desired outcomes. Emphasis is placed on active learning, including meaningful opportunities to reflect on what has been learned.

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). ***Educational Psychologist*, *42*** **(2), 99–107. https://doi.org/10.1080/00461520701263368**

Criticisms of problem-based learning (PBL) and inquiry learning (IL) are rebutted by pointing out the differences between well designed learning experiences and more loosely planned discovery learning. The authors agree that there is little evidence for the effectiveness of unguided experiential learning, i.e. leaving students free to explore whatever they choose. PBL and IL are organized around relevant and authentic problems, and students are given the tools they need to devise solutions to those problems. Evidence for the effectiveness of PBL and IL is described and cited. The authors conclude that the proper question is not if it works, but rather under what circumstances are PBL and IL appropriate, and what scaffolds need to be provided for it to succeed?

Keller, J. M. (2009). ***Motivational design for learning and performance: the ARCS model approach*** **(1st ed). New York: Springer.**

John Keller's book is based on the premise that instructors can and should accept some responsibility for motivating students. His ARCS motivation model has four components: Attention, Relevance, Confidence, and Satisfaction. A key to successfully designing instruction that motivates students is to know the audience to acquire a good sense of what will gain attention, be perceived as relevant, and be achievable with just the right level of challenge. The author balances explanations of educational psychology research findings with practical how-to instructions.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching. ***Educational Psychologist*****,** ***41*****(2), 75–86. https://doi.org/10.1207/s15326985ep4102_1**

The authors make something of a straw man argument given that few if any educational psychologists defend entirely unguided inquiry learning, but the authors' arguments for guidance are based on decades of research and have been highly cited. Their argument is based on three premises: problem solving requires a rich reservoir of long-term memory, working memory is limited, and practicing the methods of a discipline require different skills than learning the methods of a discipline. Novices need guidance and examples to build their knowledge bases before being expected to solve problems using the methods of disciplinary experts.

Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. ***Educational Psychologist*****,** ***38*****(1), 43–52. https://doi.org/10.1207/S15326985EP3801_6**

Humans have limited capacity to process information through their auditory/verbal and visual/pictoral channel. Instruction should be designed to avoid overloading those channels. The authors describe research-based, specific ways to reduce cognitive load, including converting printed words to narration, segmenting, pretraining, being as concise and coherent as possible, signaling most important content, aligning words with pictures, eliminating redundancy, and making sure verbal and visual content is synchronized. Although focused on online learning, the principles apply to any type of instruction that uses both auditory and visual means of conveying information.

Tomlinson, C. A. (2005). *The differentiated classroom: responding to the needs of all learners* (Special ed). Upper Saddle River, NJ: Pearson/Merrill Prentice Hall.

Carol Ann Tomlinson was a public school teacher for 21 years and has been a pioneer in techniques to reach learners with diverse skills and interests. The principles espoused in this book play a key role in Universal Design for Learning. The examples are primarily of younger students, but most of the principles are applicable to higher education. These include stations or centers that students rotate through, personal learning agendas, different modes of introduction to a topic, and tiered activities. The book includes a wealth of practical advice on how to implement differentiated instruction.

Wiggins, G. P., & McTighe, J. (2006). *Understanding by design* (Expanded 2nd ed). Upper Saddle River, N.J: Pearson Education, Inc.

This is widely considered the standard text on instructional design. Authors Grant Wiggins and Jay McTighe describe backward design as a process of first determining what one want students to understand (versus be able to regurgitate), determining how to assess understanding, then figuring out what activities and assignments are best able to lead to measurable understanding. They describe six types of understanding: explanation, interpretation, application, perspective, empathy, and self-knowledge. The book is filled with concrete examples and practical advice.

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Chi, M. T. H., & Wylie, R. (2014). The ICAP Framework: Linking Cognitive Engagement to Active Learning Outcomes. *Educational Psychologist*, *49*(4), 219–243. https://doi.org/10.1080/00461520.2014.965823

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