Evaluating Lesson Design and Implementation within the ICAP Framework

Rod D. Roscoe (rod.roscoe@asu.edu) and Pedro J. Gutierrez (pgutier1@asu.edu)
Arizona State University, 7271 E. Sonoran Mall, Santa Catalina Hall, Mesa AZ 85212

Ruth Wylie (ruth.wylie@asu.edu) and Michelene T. H. Chi (mtchi@asu.edu)
Arizona State University, Learning Sciences Institute, PO Box 872111, Tempe AZ 85287

Abstract: The ICAP framework provides a theory of cognitive engagement based on overt learning activities that may inform instructional design. In ongoing work to investigate ICAP as a theoretically-grounded instructional design system, classroom teachers participated in a workshop to learn about the framework and design lessons at varying levels. In this paper, we consider how the ICAP framework can be used in the evaluative stages of the instructional design cycle to assess learning tasks and implementation. Using an example lesson from a language arts classroom, we describe the evaluation methodology, consider how analyses revealed potential disconnects between intention and implementation, and discuss how ICAP-based evaluations may advance the design cycle by informing future lesson plans.

Instructional Design within the ICAP Framework

The ICAP framework (Chi, 2009) was initially proposed as a theory for interpreting learning research findings by examining students' *overt learning activities*. In *passive* (P) tasks, learners *receive* information without acting with or upon it (e.g., listening to a lecture). *Active* (A) tasks focus learners' *attention* or *activate* relevant knowledge (e.g., highlighting a text while reading). *Constructive* (C) tasks require *generating* ideas that go beyond the presented information (e.g., self-explaining). Finally, *interactive* (I) tasks involve dialogues in which ideas are *jointly produced* by multiple participants (e.g., revising based on peer feedback). Chi (2009) found that interactive learning tasks tended to support deeper learning than individual constructive tasks; constructive tasks tended to outperform active tasks; and active tasks outperformed passive tasks.

ICAP has recently been applied to instructional design. Although the value of constructive and interactive activities are well known, it is not easy to develop appropriate curricula that foster high levels of engagement (e.g., Allen & Tanner, 2005; Armbruster & Patel, 2009). By focusing on overt learning behaviors, ICAP offers a tractable way for teachers to design lessons that target desired levels of cognitive engagement. In this paper, we consider how ICAP can be applied to the *evaluative stages* of instructional design to assess whether lesson designs and implementation successfully matched pedagogical intentions. In the following sections, we briefly summarize instructional design, describe our evaluation methodology, and discuss a case study using this methodology drawn from a language arts lesson on complex sentences.

Stages of Instructional Design

Instructional design seeks to create lessons and experiences that build learners' understanding of the domain. Many design models incorporate planning, conducting, and evaluating processes. For example, ADDIE (e.g., Chan, 2010) describes a five-stage process of analysis, design, development, implementation, and evaluation. In *analysis*, designers gather data about the domain and learners' needs. In *design* and *development*, designers set learning objectives and create the instructional activities and learning materials. The *implementation* stage puts the lesson plan into action. Teachers deliver lectures, engage students in discussion, assign worksheets or other activities. Finally, *evaluation* examines whether the instruction was delivered as planned and identifies changes needed to improve the design. A key principle is that lesson evaluations inform the next iteration of design.

For successful instruction, the design process must also be paired with a guiding theoretical framework. Such theories provide a perspective for analyzing learner needs and specifying effective learning activities. For example, cognitive load theories posit that learners are constrained by cognitive capacity limitations, and thus instructional materials must be designed to balance sources of productive or harmful load (van Merrienboer, Kirschner, & Kester, 2003). In contrast, Keller's ARCS model (Keller, 2010) emphasizes motivational factors of attention, relevance, confidence, and satisfaction. Instructional materials must be designed to grab attention, make the value of the subject matter salient, and support learners' confidence.

ICAP offers a theoretical perspective for instructional design that focuses on overt learning behaviors for deeper understanding (Chi, 2009). Learners' needs are analyzed with respect to desired levels of cognitive engagement and then overt learning activities can be specified to suit those aims. For example, when recall of key terms is the goal, then passive or active tasks may be sufficient. However, if students must develop a deep and flexible understanding, then constructive or interactive tasks may be better. This paper extends work on ICAP as an instructional design tool by considering how the framework can be used to evaluate lesson design.

Participating teachers created and implemented ICAP-based lessons during their school year and later submitted their materials and examples of students' work to the research team. If ICAP is to be viable for instructional design, then the framework must demonstrate utility for critically reviewing lesson implementation. The evaluation process must be able to reveal adherence to (or departures from) curricular goals and inform ways to improve future lesson plans (i.e., complete the design cycle). In this paper, we apply the ICAP framework to consider two key questions: *Did teachers' lessons fulfill their intentions to provide passive, active, constructive, or interactive learning experiences? Did students' overt activities and responses manifest the target levels of cognitive engagement*?

Method

Teacher Professional Development

Ten middle school and high school teachers participated in a workshop introducing ICAP. Teachers represented a diverse selection of domains, including history, language arts, general science, physics, chemistry, and earth science. Participating teachers reported an average of 9.7 years of teaching experience, including new and veteran teachers. Four teachers had completed or were enrolled in a master's degree program. The workshop began with an introduction to the ICAP framework, including a detailed description of each level, examples of overt activities within each level, and hypothesized cognitive processes associated with each level. In addition, we also discussed logical and practical issues involved with implementing ICAP lessons into a classroom and gave two full days to develop two lessons based on ICAP. Teacher learning and understanding was assessed through pretests, posttests, surveys, and evaluating the lessons they created during the workshop.

The ten teachers, with one exception, each created two lessons within their areas (19 lessons total). For example, an earth science teacher created and contrasted active and interactive lessons on (a) the science of decay and (b) earth systems. *Science of Decay* discussed principles of decomposition, such as the role of key microorganisms (e.g., bacteria and fungi). *Earth Systems* discussed various spheres (e.g., lithosphere) and the effects of natural and man-made events (e.g., volcanoes and fossil fuels). Similarly, one language arts teacher created and contrasted active, constructive, and interactive lessons for (a) analyzing sentence structure and (b) complex sentences. *Analyzing Sentence Structure* taught students to recognize fluency problems, such as choppy sentences and repetitive syntax. *Complex Sentences* taught students about independent and dependent clauses and how to combine two simple sentences into a single sentence using a subordinating conjunction. Such lesson examples demonstrate the rich and challenging concepts covered by the participating teachers. For this paper, and to demonstrate the ICAP evaluation methodology, we focus only on the Complex Sentences lesson.

Evaluation Methodology

In the first phase of evaluation, *Lesson Design Analysis*, we consider how various tasks within a lesson support the intended engagement level. This process has three steps:

1. *Review lesson plans and materials to determine the sequence of tasks that comprise the lesson.* Each task within a lesson may support a different level of engagement, and thus it is desirable to analyze them separately. Multiple tasks might be presented in one assignment (e.g., a workbook with word matching and diagramming tasks) but the level of analysis should be the constituent tasks.

2. *Categorize each task based on the level of cognitive engagement required.* Each task can be evaluated for whether the required overt behaviors are passive, active, constructive, or interactive. For example, matching terms and definitions is "active" whereas drawing a diagram is "constructive."

3. *Categorize the overall lesson based on the pattern of constituent tasks.* The holistic categorization is based on the *highest level of engagement* demonstrated by *at least one-third* of the tasks. For instance, if a lesson has 10 tasks with 3 active (30%), 5 constructive (50%), and 2 interactive (20%), then the lesson is labeled "constructive" because interactive tasks comprise less than 33% of the lesson.

Even well-designed lessons cannot guarantee student compliance. In the second phase, *Student Work Analysis,* we consider how students' overt responses exhibit a given engagement level. This process has three steps:

1. *Obtain and review available records of student work and products.* Student work may include notes taken while watching a video, answers to worksheet problems and questions, video recordings of students' interactions during a lesson, assessment tests, and other materials created by students.

2. *For each activity or task, develop a coding scheme to assess students' exhibited level of cognitive engagement.* The coding process should be specific to the assignment and engagement level. For example, active tasks might be coded based on completeness and constructive tasks might be coded

based on the number of elements generated. In some cases, the analysis may reveal gaps in the data (e.g., no record of students' interactions), which may imply ways to improve future lesson activities.

3. *Implement the coding scheme(s).* Code the data and establish expectations for the range of scores that indicate the target engagement level. For instance, if a worksheet is intended to be "constructive," what range of scores would support the interpretation that students were indeed constructive?

Table 1: Complex Sentences lesson task list and ICAP categorization (italics indicate coded actions).

Task Order and Description		Category
Active Version (n = 20 students)		
1	*Copy* definitions of "independent clause" and "dependent clause" in a notebook	Active
2	*Read* pre-made flashcards containing example clauses	Passive
3	Mix and match flashcards to *create* complex sentences	Constructive
4	*Write* the generated sentences in a notebook	Active
5	Use flashcards to *create* groupings based on clause types	Constructive
6	*Write* grouped clauses in a notebook	Active
7	*Glue* the notes into a notebook to use as examples	Active
8	Practice *combining* two short sentences into one complex sentence	Constructive
Constructive Version (n = 29 students)		
1	*Generate* definitions of "independent" and "dependent"	Constructive
2	*Check* the definitions using the dictionary	Active
3	Answer *comparison* questions about their definitions versus the dictionary	Constructive
4	*Write* the correct definitions in a notebook	Active
5	*Generate* definitions of "independent clause" and "dependent clause"	Constructive
6	*Check* the definitions using the dictionary	Active
7	Answer *comparison* questions about their definitions versus the dictionary	Constructive
8	*Glue* the notes into a notebook to use as examples	Active
9	*Identify* correctly punctuated complex sentences and *justify* the choice	Constructive
10	Teacher *tells* the students which answers are correct	Passive
11	*Create* a general rule for using commas in complex sentences	Constructive
12	Practice *combining* two short sentences into one complex sentence	Constructive
Interactive Version (n = 30 students)		
1	*Generate* definitions of "independent" and "dependent"	Constructive
2	*With a partner*, *compare* definitions and check them with the dictionary	Interactive
3	*Generate* a final definition based on original, partner, and dictionary versions	Constructive
4	*Write* the correct definitions in a notebook	Active
5	*With a partner, generate* definitions of "independent clause" and "dependent clause"	Interactive
6	*Check* the definitions using the dictionary	Active
7	*With a partner*, *compare* definitions and check them with the dictionary	Interactive
8	*Glue* the notes into a notebook to use as examples	Active
9	*With a partner, identify* correctly punctuated complex sentences and *justify* the choice	Interactive
10	Teacher *tells* the students which answers are correct	Passive
11	*With a partner, create* a general rule for using commas in complex sentences	Interactive
12	*As a whole class*, *discuss* sentence rules and definitions	Interactive
13	*Glue* the notes into a notebook to use as examples	Active
14	*With a partner,* practice *combining* two short sentences into one complex sentence	Interactive

Results

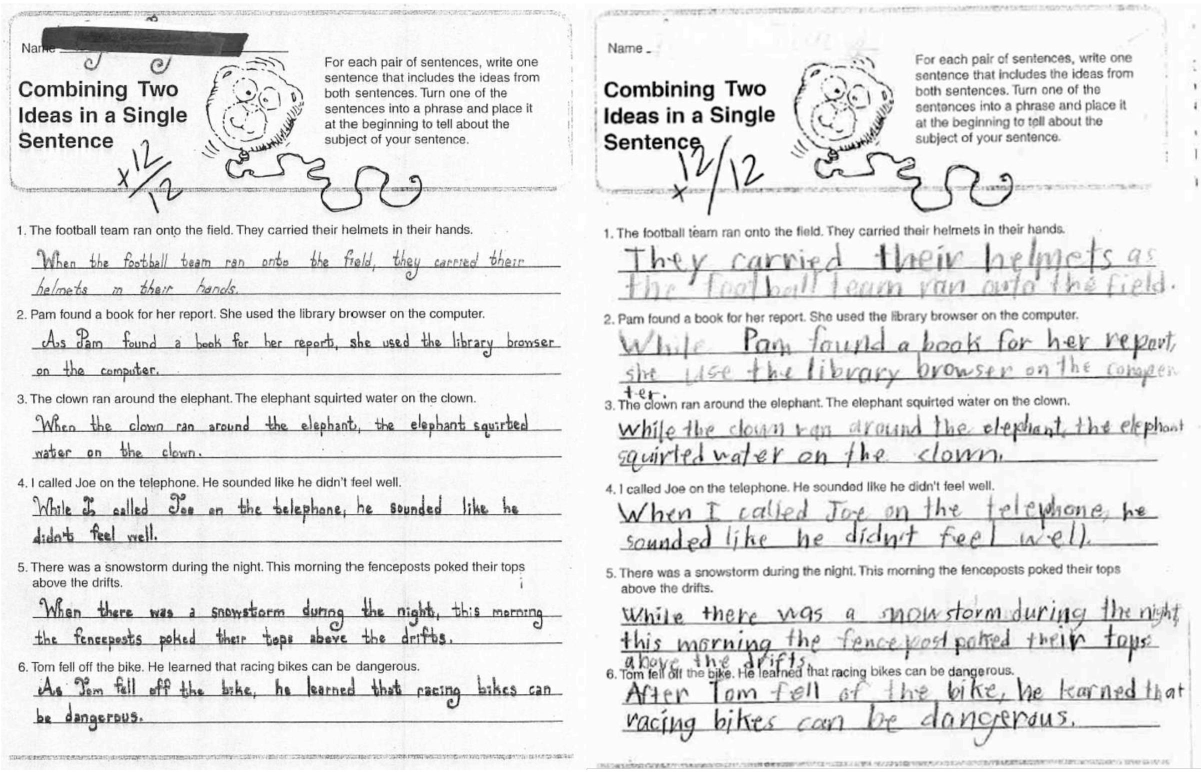
Lesson Design Analysis: Complex Sentences

One teacher designed a lesson to teach 79 6th-grade students about independent clauses, dependent clauses, and sentence combining. The teacher developed three lesson versions to contrast active, constructive, and interactive instruction. For each lesson, the teacher's plans and materials were analyzed to determine the constituent tasks, which were then categorized according to the ICAP level (Table 1). In the Active version, students engaged in 8 tasks. Although 5 tasks (62.5%) were categorized as active, 3 tasks (37.5%) offered meaningful opportunities for constructive activity. Thus, the Active version was *recategorized* as "constructive." In the Constructive version, students completed 12 tasks: 7 were constructive (58.3%), 4 were active (33.3%), and 1 was passive (8.3%). Thus, the teacher's original "constructive" label for this lesson was retained. Finally, in the Interactive version, students completed 14 tasks: 7 were interactive (50.5%), 2 were constructive (14.3%), 4 were active (28.6%), and 1 was passive (7.1%). Thus, the teacher's original "interactive" label for this lesson was retained.

This evaluation demonstrated two key points regarding lesson design. First, teachers' intentions may be countered by incorporating tasks of a different level. The teacher's active lesson contained constructive tasks involving generation of examples, resulting in the lesson being relabeled as constructive. Importantly, we are not arguing that lessons should only contain tasks of one type; learning tasks at different levels each have their role to play. Although ICAP does not specify how activities should be sequenced, a student debate (interactive) may be more productive if debaters first articulate their arguments on their own (constructive), which may require reading and note-taking (active) to collect evidence. The core idea, however, is that if the teacher's goal is to support a particular level, then the types of activities included in the lesson must be carefully chosen.

Student Work Analysis

An analysis of all cases of student products was beyond the scope of this paper. To exemplify a student work analysis, we consider students' responses on one worksheet (Figure 1) in which they practiced combining sentences (i.e., in Table 1, see Active task #8, Constructive task #12, and Interactive task #14).


Name [redacted]

Combining Two Ideas in a Single Sentence

For each pair of sentences, write one sentence that includes the ideas from both sentences. Turn one of the sentences into a phrase and place it at the beginning to tell about the subject of your sentence.

+12/12

1. The football team ran onto the field. They carried their helmets in their hands.
When the football team ran onto the field, they carried their helmets in their hands.
2. Pam found a book for her report. She used the library browser on the computer.
As Pam found a book for her report, she used the library browser on the computer.
3. The clown ran around the elephant. The elephant squirted water on the clown.
When the clown ran around the elephant, the elephant squirted water on the clown.
4. I called Joe on the telephone. He sounded like he didn't feel well.
While I called Joe on the telephone, he sounded like he didn't feel well.
5. There was a snowstorm during the night. This morning the fenceposts poked their tops above the drifts.
When there was a snowstorm during the night, this morning the fenceposts poked their tops above the drifts.
6. Tom fell off the bike. He learned that racing bikes can be dangerous.
As Tom fell off the bike, he learned that racing bikes can be dangerous.

Name

Combining Two Ideas in a Single Sentence

For each pair of sentences, write one sentence that includes the ideas from both sentences. Turn one of the sentences into a phrase and place it at the beginning to tell about the subject of your sentence.

+12/12

1. The football team ran onto the field. They carried their helmets in their hands.
They carried their helmets as the football team ran onto the field.
2. Pam found a book for her report. She used the library browser on the computer.
While Pam found a book for her report, she use the library browser on the computer.
3. The clown ran around the elephant. The elephant squirted water on the clown.
While the clown ran around the elephant, the elephant squirted water on the clown.
4. I called Joe on the telephone. He sounded like he didn't feel well.
When I called Joe on the telephone, he sounded like he didn't feel well.
5. There was a snowstorm during the night. This morning the fenceposts poked their tops above the drifts.
While there was a snow storm during the night this morning the fence post poked their tops above the drifts.
6. Tom fell off the bike. He learned that racing bikes can be dangerous.
After Tom fell of the bike, he learned that racing bikes can be dangerous.

Figure 1. Two example worksheets from the Complex Sentences lesson. The grades provided by the teacher (e.g., "+12/12") were not included in the ICAP evaluation process.

The worksheet contained six pairs of sentences. Students could choose the conjoining word, where to place the conjoining word (i.e., at the start of the first sentence or between the sentences), and whether to maintain or swap the ordering of the original sentences. To code for constructive activity, we examined the variability of students' strategies. Students earned up to 6 points based on whether they used a single *word insertion strategy* for all pairings (0 points) versus varying the strategies equally (6 points). Likewise, students earned up to 6 points based on whether all sentences used one *ordering strategy* (0 points) or varied the ordering strategies equally (6 points). Finally, students earned up to 6 points for *each unique conjoining word* (1 point per word). Higher total scores (i.e., > 12 points) showed more constructive activity by implementing more varied strategies whereas lower scores (i.e., < 6 points) indicated less constructive activity (Table 2).

Not every student completed the assigned tasks ($n = 69$). Across students with available data, average constructive activity for the worksheet was only 6.0 ($SD = 3.3$). Students showed the most constructive activity in terms of varying conjoining word choice rather than other strategies, but students exhibited minimal constructive activity, overall. According to the ICAP framework, students in the interactive version should have outperformed the others, which appeared to be untrue in this case. However, without data on partners' contributions or dialogue, it was impossible to diagnose what occurred between partners (e.g., whether they were co-constructing knowledge or engaging in off-task conversation).

The results of this student work analysis demonstrated a potential disconnect between lesson intentions and actual implementation by students. Although the task offered several opportunities to constructively explore different sentence combining techniques, students used relatively few of them. Instead, students may have been using only one or two rules for combining sentences by rote instead of thoughtfully constructing new sentences.

Table 2: Mean (and standard deviation) scores for worksheet constructive activity.

Strategy	Active (n = 19)	Constructive (n = 26)	Interactive (n = 24)	F	p
Total Score	5.5 (2.5)	6.8 (3.6)	5.5 (3.6)	1.28	.284
Word Insertion	1.3 (1.5)	2.1 (1.9)	0.8 (1.5)	3.93	.024
Sentence Ordering	0.4 (1.1)	1.6 (2.2)	1.1 (1.9)	2.34	.104
Word Variability	3.8 (1.2)	3.1 (1.1)	3.7 (1.5)	1.92	.155

Conclusion

The methodology presented here suggests that ICAP is useful and viable for instructional design. In this paper, we considered how ICAP principles can be used to assess lesson design and implementation. Such evaluations can reveal how the individual tasks that comprise a lesson may support or undermine broader curriculum goals. For example, learning tasks might support a lower level of cognitive engagement than intended or students may not enact the task at the target level. Such failures of instructional design are not new but ICAP provides a framework for analyzing and specifying these issues in a fine-grained manner.

Importantly, ICAP also informs the analysis and development of new lessons. When combined with evaluation, ICAP can guide iterative lesson design and improvements. For example, in the Complex Sentences lesson, the teacher might revise the instructions for the sentence combining task (Figure 1) to explicitly require constructive use of diverse strategies. Similarly, the teacher might create more precise sequences of active, constructive, or interactive tasks that build from lower to higher levels of cognitive engagement. Although ICAP does not specify an ideal ordering of tasks or engagement levels, researchers could use this methodology to test hypotheses about instructional sequences. That is, one might contrast the efficacy of lessons that progress from low-to-high cognitive engagement, high-to-low cognitive engagement, or stagger the engagement levels.

Any evaluation method is limited by the available data. For instance, no trace data were collected regarding students' dialogue in the interactive version of the Complex Sentences lesson. Thus, it was impossible to evaluate whether students co-constructed ideas while combining sentences. For researchers and educators seeking to use ICAP for instructional design, care must be taken to create and collect diagnostic examples of student work. If students are supposed to be constructive, do their materials allow them to record their generated responses? If students are supposed to be interactive, do their materials allow them to record their individual or mutual contributions to the final products? Addressing such questions further supports iterative instructional goals (e.g., asking partners to record their contributions may encourage interaction) and evaluation goals.

References

Allen, D., & Tanner, K. (2005). Infusing active learning into the large-enrollment biology class: Seven strategies, from the simple to complex. *Cell Biology Education, 4*, 262-268.

Armbruster, P., Patel, M., Johnson, E., & Weiss, M. (2009). Active learning and student-centered pedagogy improve student attitudes and performance in introductory biology. *CBE-Life Sciences Education*, *8*, 203-213.

Chan, J. F. (2010). *Designing and developing training programs: Pfeiffer essential guides to training* basics. Wiley and Sons: San Francisco, CA.

Chi, M. T. H. (2009). Active-Constructive-Interactive: A conceptual framework for differentiating learning activities. *Topics in Cognitive Science*, *1*, 73-105.

Keller, J. M. (2010). *Motivational design for learning and performance: The ARCS Model approach.* New York: Springer.

Merrienboer, J. J. G., Kirschner, P. A., & Kester, L. (2003). Taking the load off of a learner's mind: Instructional design for complex learning. *Educational Psychologist, 38*, 5-13.

Acknowledgments

The research reported here was supported by the Institute of Education Sciences, U.S. Department of Education, through Grant 305A110090 to Arizona State University. The opinions expressed are those of the authors and do not represent views of the Institute or the U.S. Department of Education. The authors would like to thank Wan-Ting Huang, Seokmin Kang, Matthew Lancaster, Derek Stark, and David Yaghmourian for their assistance.

