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Active-Constructive-Interactive: A Conceptual Framework for Differentiating Learning Activities

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Abstract

Active, constructive, and *interactive* are terms that are commonly used in the cognitive and learning sciences. They describe activities that can be undertaken by learners. However, the literature is actually not explicit about how these terms can be defined; whether they are distinct; and whether they refer to overt manifestations, learning processes, or learning outcomes. Thus, a framework is provided here that offers a way to differentiate *active, constructive,* and *interactive* in terms of observable overt activities and underlying learning processes. The framework generates a testable hypothesis for learning: that *interactive* activities are most likely to be better than *constructive* activities, which in turn might be better than *active* activities, which are better than being *passive.* Studies from the literature are cited to provide evidence in support of this hypothesis. Moreover, postulating underlying learning processes allows us to interpret evidence in the literature more accurately. Specifying distinct overt activities for *active, constructive*, and *interactive* also offers suggestions for how learning activities can be coded and how each kind of activity might be elicited.

Keywords: Learning activities; Active; Constructive; Interactive

Teachers open the door,
But you must enter by yourself.

Tell me and I forget.
Teach me and I remember.
Involve me and I learn.

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Chinese proverbs and popular quotes (such as the second one from Benjamin. Franklin above) suggest, with words like ''enter'' and ''involve,'' that learning is an *active* process. Educators and psychologists tell us that learning is a *constructive* process. Situated theorists and psycholinguists inform us that learning is an *interactive* process. Although all three terms view learners as active participants in their own learning experiences, are these three terms distinct? Can they be differentiated in terms of both the overt activities and their corresponding internal cognitive processes?

There are several advantages to addressing these questions. First, differentiating the *overt activities* can guide designers of learning environments in knowing which activity they are in fact eliciting from students. Second, differentiating the potential underlying *cognitive processes* corresponding to each activity may explain their differential effectiveness in mediating learning. Third, differentiating them will also allow us to understand some discrepant results in the literature, as will be illustrated later.

Although the three terms—*active, constructive,* and *interactive*—have been used extensively in the literature, only *constructive* has been defined more explicitly and frequently, such as that it is meaningful learning in which a learner actively builds a mental model of the system she is to learn (Mayer & Wittrock, 1996). The other two terms—*active* and *interactive,* have received much less attention in terms of explicit definitions. Instead, they are often used either synonymously or alongside with *constructive,* such as ''the generally accepted view that students *actively construct* their mathematical ways of knowing…'' (p. 13, italics added, Cobb, 1994), or ''learning is characterized by the subjective re*construction* of societal means and models through negotiation of meaning in social *interaction''* (Bauersfeld, 1988, p. 39). Moreover, these terms are often used in such contrasting contexts that their meanings are intuitive. For example, *active* is contrasted with *passive* (Schank, 1994); *constructionism* (referring to what a learner does) is contrasted with *instructionism* (referring to what an instructor does; Kafai, 2006); *co-participation* (referring to an activity) is contrasted with *cognitive reorganization* (referring to cognitive processes; Cobb, 1994), both as definitions of *constructive*. In short, although *constructive* as been defined more often, neither *active* nor *interactive* has been directly defined, so that it is not clear whether the three terms mean the samething or something different.

While these terms are often used interchangeably and are intuitively understood, each of these terms does have other unique meanings associated with it. For example, the noun *activity* is used in the situative perspective to refer to an entire system of activity, involving the teacher, the learners, the curriculum materials, the software tools, and the physical environment. Analyses of such a system include analyses of coordination or *interaction*, either in terms of patterns of conversational interactions (such as turn taking, opening and closing of topics, mechanisms of repair) or in terms of coordinating behaviors for joint activity (Greeno, 2006). From this situated perspective, the term *activity* seems to mean *interactions.*

The term *constructivism* is often used to mean *discovery learning*. The contrast here is between learning from *being told* (direct instruction) versus learning from *discovering* on one's own (in which students *construct* the rules and relationships they need).

Notice that this contrast is also one between what an instructor does (telling in direct instruction) compared with what a student does (constructing or discovering knowledge).

Finally, the term *interactive* is also used to refer to a body of literature that focuses on interacting with a computer system or pedagogical agent. Moreover, in these cases, *interactive* often describes the system, such as an *interactive video* (Schwan & Riempp, 2004), referring to the degree of control or adaptiveness a user might have with a system, without necessarily having to give a response. For example, a user may have contingent control over the timing and duration of a presentation (Narayanan & Hegarty, 2002). *Interactive* can also refer to the amount of feedback, guidance, or scaffolding that a system can give. For example, a low *interactive* tutoring system might be one that does not give step-by-step feedback, but only gives feedback for the correctness of the final answer. Thus, the term *interactive* in this body of literature often describes a system, rather than the interactions between a learner and a system.

In sum, it appears that *active, constructive*, and *interactive* are not clearly defined nor clearly differentiated. The goal of this paper is to provide a framework differentiating *active, constructive*, and *interactive*, in terms of their overt activities and their potential corresponding cognitive processes. This framework then generates a hypothesis that will be tested with evidence in the literature. This framework is not meant to be *definitive*, but only as a starting point to begin thinking about the roles of overt learning activities and their relationship to internal processes.

To underscore this point, the conceptual framework to be presented here views being active, constructive, and interactive as types of *overt learning activities,* undertaken by students *while learning* from a resource (such as a text, a virtual environment, a tutoring system, etc.). The focus is strictly on the learners from the learners' perspective, independent of what an instructor or a system does. Thus, in differentiating *active, constructive,* and *interactive,* the framework compares and contrasts one learning activity with another learning activity during a learning phase, rather than comparing a student's activity and an instructor's activity.

This paper has two main sections. In the first section, a taxonomy is provided that differentiates *active, constructive,* and *interactive*. This taxonomy generates a testable hypothesis. In the second section, the hypothesis is described, and three kinds of evidence from the literature in support of this hypothesis are presented. The paper then concludes with a brief discussion about the utility of this framework, in terms of suggesting what kind of instructional manipulations might elicit each kind of activities, and describes challenges that have been encountered.

1. A proposed taxonomy

This taxonomy attempts to characterize *active, constructive,* and *interactive* activities in a way that allows us to classify overt activities that have been used in existing studies in the literature. Ideas in the literature for how these activities might be elicited will also be briefly described. Then, *potential* cognitive processes that *may underlie* each of these learning activities will be postulated. The words *potential* and *may underlie* are emphasized because the majority of learning studies do not explicitly assess what cognitive processes are actually occurring, so one can only hypothesize the relationship between them and overt activities. Finally, how these cognitive processes can mediate learning will be suggested.

1.1. Overt activities and instructional manipulations to elicit them

As stated above, for this taxonomy, a learning activity used in a study will be classified on the basis of a learner's overt, externally observable activities, as either *active, constructive*, or *interactive.* These overt activities are visible, can be elicited and manipulated by the instructor or designer of a learning environment, can be assessed in terms of their frequency of occurrences, and can be coded in a variety of ways and analyzed as evidence of mediators of learning. Examples of overt activities of each kind will be presented below, along with ideas of how they can be elicited.

1.1.1. Being active

Being active can be characterized as doing something (often involving physical movement) while learning. For example, in a virtual environment, if students explore the environment by *steering* and *peddling* a stationary bike while they travel through a virtual environment, that would be considered an *active* activity (Tong, Marlin, & Frost, 1995). On the other hand, if students were merely *watching* a video recording of what the active participants saw but without being able to explore or manipulate the environment, that would be considered to be *passive* in that, at least overtly, the student is not doing anything.

Using this stricter criterion of doing something physically as an indication of *being active*, there are many studies in the literature that provide wonderful examples of overt activities that can be characterized as *being active* during learning. Some obvious ones are as follows: *looking* at and *searching* some specific locations on a static chessboard (Chase & Simon, 1973) or at a static Lego model in order to copy or reproduce it (Azmitia, 1988),[1] *pointing* to or gesturing at what one is reading or solving (Alibali & DiRusso, 1999), *gazing* at what one is thinking about as measured by eye movement duration (Paterson et al., 2007), *underlining* or *copying-and-pasting* some parts of a text (Igo, Bruning, & McCrudden, 2005), *repeating* sentences verbatim or *copying* problem solution steps (VanLehn et al., 2007), *summarizing* paragraphs using delete and substitution rules (Brown & Day, 1983), *manipulating* video tapes such as pausing and rewinding them (Chi, Roy, & Hausmann, 2008), *rotating* objects (James et al., 2002), *selecting* from a menu of choices (Conati & VanLehn, 2000), and so forth. This set of *active* activities will also be referred to as ''engaging activities'' (Table 1, rows 1 & 2).

Note that the term *active* is used in this taxonomy in a different way from the more traditional use of the term *active* in the memory literature. In that memory literature, an activity, such as rehearsing by repeating words, is considered *passive,* but in this taxonomy, it is considered *active*. The difference is that in this taxonomy, the term *active* characterizes the overt activity per se, whereas in the memory literature, the term *active* refers to the outcome of learning and memory. For instance, rehearsing or repeating words is a *passive* strategy of learning because it leads to less learning and remembering as compared to deeper levels of processing.

There are numerous ways one can also elicit such engaging activities. For example, in order to make students focus their gaze on some aspects of the learning materials, one can bold the font or put the important information inside a box if the learning materials are presented in a text or animate the important information if it is presented online. In a classroom context, an instructor could point to or gesture at the important materials on the blackboard; and in math classes, teachers can provide manipulatives such as Dienes' blocks for students to use. In a virtual laboratory setting, such as a chemistry lab, students can do hands-on laboratory work using flasks, tubes, liquid, and so forth. Thus, the goal of this type of eliciting tactics is to engage the learners. Of course, there is no guarantee that these activities engage the learners deeply. Learners can select from a menu mindlessly or manipulate Dienes' blocks playfully. However, it is likely that by doing these *active* activities, learners become more engaged with the learning materials than by not doing these activities.

Table 1
Characteristics, overt activities, and cognitive processes, for active, constructive, and interactive activities, from the learner's perspective

	Active	Constructive	Interactive
Characteristics	Doing something physically	Producing outputs that contain ideas that go beyond the presented information	Dialoguing substantively on the same topic, and not ignoring a partner's contributions
Overt activities	*Engaging Activities* Look, gaze, or fixate Underline or highlight Gesture or point Paraphrase Manipulate objects or tapes Select Repeat	*Self-construction Activities* Explain or elaborate Justify or provide reasons Connect or link Construct a concept map Reflect, or self-monitor Plan and predict outcomes Generate hypotheses	*Guided-construction Activities* in *Instructional Dialogue:* Respond to scafffoldings Revise errors from fdbk *Sequential or Co-construction Activities* in *Joint Dialogue:* Build on partner's contr Argue, defend Confront or challenge
Cognitive processes	*Attending Processes* Activate existing knowledge Assimilate, encode, or store new information Search existing knowledge	*Creating Processes* Infer new knowledge Integrate new information with existing knowledge Organize own knowledge for coherence Repair own faulty knowledge Restructure own knowledge	*Jointly Creating Processes* Creating processes that incorporate a partner's contributions

1.1.2. Being constructive

How is *being constructive* different from *being active*? There is another set of overt activities that can be characterized as more *constructive* because in undertaking them, learners produce some additional outputs; and such outputs often (but not always) contain new content-relevant ideas that go beyond the information given. For example, in an active type of activities such as *underlining,* learners are not producing additional outputs, instead, the outputs—in this case the underlined sentences, are a part of the originally presented materials. In contrast, in a *constructive* type of activity such as self-explaining, learners are articulating what a text sentence or a solution step means to them out loud. In so doing, learners produce utterances that have been referred to as self-explanations (Chi, Bassok, Lewis, Reimann & Glaser, 1989), and these self-explanations often contain elaborations and ideas that are not explicitly stated in the text; therefore, they go beyond the provided information. Furthermore, by articulating, the learners are also *active* since they are actively generating utterances visibly. Therefore, the activity of being *constructive* subsumes being *active*.

To reiterate, a producing type of activity can be classified as *constructive* only if the outputs contain ideas that go beyond and are not explicitly presented in the learning materials. Otherwise such a *constructive* activity becomes merely an *active* activity. For example, in articulating, if the self-explanations are either nonsensical, irrelevant, or verbatim utterances, then a learner is merely being *active* and not *constructive.* But if the produced self-explanations are meaningful elaborations that go beyond what was presented, then the learner has been *constructive.* Thus, in order to know whether a learner is actually generating new ideas in a constructive activity, one must analyze the content of the outputs.

There are many examples of overt *constructive* activities that have been studied besides self-explaining (Chi, de Leeuw, Chiu, & LaVancher, 1994), such as *drawing* a concept map (Biswas, Leelawong, Schwartz, Vye, and Teachable Agents Group at Vanderbilt, 2005), *taking* notes (Trafton & Trickett, 2001), *asking* questions (Graesser & Person, 1994), *posing* problems (Mestre, 2001), *comparing and contrasting* cases (Schwartz & Bransford, 1998), *integrating* text and diagram or across multimedia resources (Bodemer, Ploetzner, Feuerlein, & Spada, 2004), *making* plans (Pea & Kurland, 1984), *inducing* hypotheses (Suthers & Hundhausen, 2003), *drawing* analogies (Chinn & Malhorta, 2002), *generating* predictions (Klahr & Nigam, 2004), *reflecting* and *monitoring* one's own understanding and other self-regulatory activities (Azvedo, Greene, Moos, Winters, & Godbole-Chaudhuri, 2006), *constructing* timelines for historical phenomena (Dawson, 2004), and so on.

Constructive activities, as defined here, have two characteristics. The first, as stated above, is that they often require learners to produce some sort of overt outputs, such as explanations from self-explaining, notes from note-taking, hypotheses from inducing, questions from question-asking, predictions from generating, concept maps from drawing, self-report assertions such as ''I don't understand'' from monitoring, perhaps in the context of other utterances such as problem-solving protocols. A second characteristic of *constructive* activities is that they tend to ask learners to produce some outputs that are not contained in or presented in the learning materials. For example, asking students to compare-and-contrast two worked-out examples requires the learners to say what is the same or different between two worked-out examples, when the instructional materials obviously did not mention this same-or-different information about the two examples. Similarly, asking students to self-explain what a sentence means to them obviously is requiring them to infer new information about that sentence that was not explicitly presented. And asking students to construct a concept map obviously requires students to produce new information about causal relations among concepts that were not spelled out in a text or other sources.

By the very nature of these two characteristics, the assumption here is that in the process of *constructing,* this set of producing-type activities is more likely to encourage and necessitate producing outputs that contain ideas that go beyond the explicitly presented information than the set of activities listed as *active* (see Table 1, second row). This greater likelihood is due to the fact that a constructive type of activity requires the generation of externalized ideas that are not explicitly presented. For example, one is more likely to generate additional information and ideas from comparing and contrasting two worked-out examples, let's say, than by copying two examples, simply because the processes of comparing and contrasting requires the generation of similarities and differences. Statements or features of similarities and differences are not presented in the original learning materials.

There are two caveats or issues to be noted about *constructive* activities. The first issue has to do with whether the outputs must be externalized. Even though the majority of the studies rely on externalized outputs, the outputs can be internal ones. For example, one could self-explain covertly. However, from a researcher's point of view, internal outputs will simply be more difficult to assess. Moreover, there may be some advantages to externalizing one's *constructive* outputs. For instance, suppose a student is asked to draw a diagram of a geometry problem. By doing so, the student may see other relations in the diagram that was not apparent to her prior to drawing, such as that the angles cut by a transversal line add up to 180 degrees. The point is that the outputs, once externalized, become new materials from which a student can examine and infer further new knowledge.

The second issue concerns the content of the outputs. The assumption is that undertaking an output-producing type of *constructive* activities does not guarantee, but are likely to promote, the generation of new information. Take question-asking as an example. If a student asks a shallow question that is essentially a verbatim repetition of a text sentence, except converted into a question format, then this student is not being *constructive*; instead, she is merely being *active* by engaging with the materials. Thus, question-asking itself is not, by definition, a *constructive* activity. However, the assumption here is that in the process of generating questions, students are more likely to produce ideas that go beyond the explicit information presented in the instruction. In short, the activity of producing these sorts of outputs makes them *active.* However, such an activity become *constructive* if we can ascertain that the content of the outputs contains information that goes beyond what was presented.

There are many kinds of manipulations that may encourage and elicit *constructive* activities. One method is direct prompting. Using self-explaining as an example of a constructive activity, one can elicit it by prompting students to self-explain (Chi et al., 1994), either by explicitly asking a learner to do so using generic prompts or modeling it for the students initially (Bielaczyc, Pirolli, & Brown, 1995), or embedding questions in a text or other learning resources (Davis, 2003). Indirect methods can also be used to elicit self-explaining and other constructions. For example, by using diagrams (Ainsworth & Loizou, 2003) or making a text more sparse, learners might be encouraged to fill in the blanks (McNamara, Kintsch, Butler Songer, & Kintsch, 1996). Another ablating method is to fade worked-out example lines or steps as a way to encourage students to fill in the missing steps (Atkinson, Renkl, & Merrill, 2003). Thus, many clever methods have tried to elicit self-explaining activities. Other *constructive* activities can also be elicited using other methods. For example, if one wanted to elicit hypotheses induction from students, one can provide a template such as a matrix for students to fill out (Suthers & Hundhausen, 2003). Again, once elicited, we can only tell that these constructive activities actually generated new domain-relevant information by analyzing the content of the outputs, such as the self-explanations, the questions asked, or the content of the matrix (for the examples above). Since these *constructive* activities can be undertaken alone, they will also be referred to as ''self-construction'' activities (see Table 2, row 2, column 2).

1.1.3. Being interactive

Being interactive can refer to several types of overt activities, such as a learner talking with another person (who can be a peer, a teacher, a tutor, a parent), responding to a system (such as an intelligent tutoring system, an animated agent), or interacting in some other physical way involving motor movements. For example, two children can be interacting physically when they jointly build a Lego model (Azmitia, 1988), or two students are interacting physically when they coordinate their use of a mouse at a single computer monitor. However, even for these latter physical situations, such as when two students work together at a single computer simulation model, learning seems to occur in the verbal discussion rather than in the motoric interactions (Milrad, 2002). This is consistent with the common assumption that discourse activities are related to cognitive processes of learning (Salomon & Perkins, 1998). Moreover, because human dialogues are both dense and rich in content, the dynamics of interactions can be interpreted more accurately by analyzing the discourse content, as compared to, let's say, a sequence of interacting gestures (although ideally one should analyze both). Finally, human dialogues have also been researched more extensively than other forms of interactions, although few studies carry out content analyses of the discourse. For all these reasons, as a starting point, the taxonomy proposed here will focus on ''dialoguing'' as the prototype of overt *interacting* activities.

Are all discourse activities the same? On the surface, the overt activity of interacting in dialogues seems straightforward and uniform. One could just describe it as two learners discussing some concept, topic, or problem. However, as in the case of utterances generated by an individual in activities characterized to be *constructive*, if the content of dialogues is analyzed, then it soon becomes apparent that different dialogue patterns emerge, and some patterns are in fact not *interactive* at all. For example, it is often the case that one partner dominates and makes most of the contributions and the other

Self-construction in *individual dialogue*:

A: "Revenues and expenses at the downtown branch changed…"

B: " Uhh"

A: "revenues have just start like increase and decrease and then leveled off so…"

B: "Umm… yeah..[typing] how do you spell fluctuate"

A "fluctuating, but not it's leveled off and…"

B: "How do you spell…"

A: "well, they generally decrease."

Co-construction in *joint dialogue*:

A: "Okay, the new system would give the- give the employees…"

B: "More time to deal with the customers."

Source: McGregor & Chi (2002)

Fig. 1. Example of self-construction in *individual dialogue* (top) and coconstruction in *joint dialogue* (bottom).

partner merely agrees or contributes with a continuer-type of response such as ''ok'' or ''uh-huh.'' (The top of Fig. 1 illustrates an example in which A self-explains and B does not make any substantive contributions.)

The dominating partner, or the ''speaker,'' participates in activities that can be characterized as explaining-to-self or explaining-to-partner. In explaining-to-self, the ''speaker'' is basically self-explaining, and in explaining-to-partner, the ''speaker'' is basically telling the partner in a teaching manner. In both types of activities, the ''speaker'' is ignoring any contributions from the partner, either because the partner hardly initiates any contributions or because the partner's contributions are not substantive. Detailed snippets of this type of noninteracting or *individual dialogues* pattern and suggestive ways of recognizing and coding them are presented in Appendix A. In short, in this type of *individual dialogue* pattern, the partners are really not interacting much, and if they take turns dominating episodes of dialogues in a cooperative or reciprocal way, then each partner is basically participating in a self-construction type of activities.

However, there are two other dialogue patterns that do characterize *interactive* activity, in the sense that both partners are making substantive contributions on the same concept or topic, and neither partner ignores each other's contributions. These are described below.

1.1.3.1. Interacting with an expert in instructional dialogues: When a learner interacts with an expert (someone who knows the content domain, such as a tutor, an instructor, or a more knowledgeable peer), the dialogues tend to take an alternative well-defined pattern. The expert often starts with a question to request a response from the student, then the expert gives corrective feedback, and then there is more extended dialogue discussing the issues (Graesser, Person, & Magliano, 1995). Two separate sets of data, one involving 11 content experts (but they were inexperienced tutors) tutoring in a conceptual domain (see Fig. 2 in Chi, Siler, Jeong, Yamauchi, & Hausmann, 2001), and the second one involving a single very experienced expert tutor tutoring in a procedural problem solving domain (see Table 3 in Chi et al., 2008), both show that the three largest categories of instructional moves tutors make are explaining, providing corrective feedback, and scaffolding or guiding the learner (including asking questions, giving hints, initiating a step, etc.). In other words, the dialogue pattern can be characterized as *instructional dialogues* in which the tutor leads and controls the conversation by explaining, giving corrective feedback, and guiding the student, while the student basically responds to the expert's leads and queries, revises errors from corrective feedback, takes few initiatives, and seldom changes the topic of conversation. (See Fig. 2 for two episodes that portray tutor scaffolding.) The learner's activities in the context of *instructional dialogues* can be referred to as ''guided-construction'' (see Table 1, row 2, column 3). As stated before, these activities are *constructive* to the extent that the student's responses are substantive and meaningful.

1.1.3.2. Interacting with a peer in joint dialogues: When a learner interacts with a peer, such interactions can sometimes characterize a pattern of *joint dialogues*, which occur when both peers make substantive contributions to the topic or concept under discussion, such as

Tutor:	Now this uhh downward force umm on B will it be only this much or ? (scaffold)
Tutee:	I guess would you (going to be) you would also have to add the also the interaction with the ground
Tutee:	So it will be - it will be normal force in relation to the ground as well or
Tutor:	This normal force umm
Tutee:	(Well this)
Tutor:	This normal force -well first look at the weight ah weight force
	Is there any other force acting downwards? (scaffold)
Tutee:	Also the force of the weight of A as well
Tutee:	So you also have [S draws down arrow from block B labeled WA = MA g]
Tutor:	Okay.

Tutor:	You have uh - uh- lets take one block at a time. (scaffold)
Tutee:	ok [looks at board between 2 blocks and then makes complex hand movement]
Tutor:	Suppose you take block A. (scaffold)
Tutee:	Alright.
Tutor:	Now um, so what are the forces acting on it? (scaffold)
Tutee:	First the gravity is pulling down/ [motions downward with hand while looking at T]
Tutor:	Pulling it down
Tutee:	And block is B is stopping it/ from pulling down.
Tutee:	Right- right.

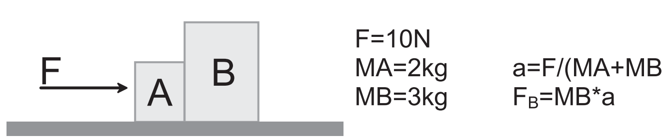
Source: Chi, Roy, & Hausmann (2008)

Fig. 2. Example of two episodes of tutor scaffolding with tutee giving a relevant substantive response.

by building on each other's contribution, defending and arguing a position, challenging and criticizing each other on the same concept or point, asking and answering each other's questions. This kind of activity is *constructive*, as defined earlier, because the learners are generating knowledge that goes beyond the information given by the learning materials. For example, the ''speaker'' who does the answering of a partner's question may be self-constructing new knowledge and ideas. Thus, *joint dialogues* refer to a pattern of interactions in which both partners make substantive contributions to the topic or concept under discussion in a more balanced way (within a given episode of analysis), rather than making contributions on different points or concepts in an unbalanced or cooperative way, as in *individual dialogues*. (See Fig. 3 for an example of *joint dialogues*.)

The substantive contributions in *joint dialogues* can be made either sequentially or in a more overlapping way. In a sequential turn-taking case, each ''speaker'' takes turn after her partner finishes his/her turn. This type of learner activities in the context of *joint dialogues* will be referred to as ''sequential-construction.'' On the other hand, if learners build on or expand upon each other's line of reasoning by completing each other's sentences rather than waiting for the partner to finish her thoughts and ideas before interjecting, this type of learner activity in *joint dialogues* will be referred to as ''coconstruction.'' (See Fig. 1, bottom, for an example.)

Besides sequential-construction and co-construction, individuals in *joint dialogues* can also participate in self-construction, in which each ''speaker'' incorporates the contributions of the partner and extends her own understanding. (This differs from self-construction in *individual dialogues,* e.g., explaining-to-self or to-other, in which the ''speaker'' ignores the partner's nonsubstantive contribution). Self-construction in *joint dialogues* is a novel



Sara:	Yeah. It's just-it didn't say? I thought it said each of them. [Reads: Find the acceleration of the blocks.] To me that says find the acceleration of each block. You know like, since they're two *different* kilograms.
Jill:	It's going to be, the *same* though.
Jill:	Because like, if we, go like this [pushes a book and pencil], and I do this, they're both moving at the *same* acceleration.
Sara:	[Talks to Experimenter: 4 turns]
Sara:	Because if you-well you can get a *different* acceleration by breaking it up though.
Jill:	Oh wait. You know what? The acceleration will be the *same* for both of them. Acceleration is the *same* for both of them. Force acting on block B, is different from force acting on block A.
Sara:	Ok. Because their mass, is *different*.
Jill:	Yeah. Because-yeah.

Fig. 3. Example of a joint explanation in which both partners are making substantive contributions.

dialogue pattern proposed here; thus, we have not attempted to code it. It is not depicted in Table 1, row 2, column 3.

How can dialogues be elicited? On the surface, this may appear straightforward. One can elicit it naturally by pairing students to work together. One partner may naturally discuss with the other, or one can also instruct a student to explain to another (Roscoe & Chi, 2007a). However, it is tricky to elicit a specific kind of dialogue pattern, as will be mentioned later. Many studies do exist that have offered ways to script collaborative dialogues such as by having students use simple sentence openers (Soller, Linton, Goodman, & Lesgold, 1999), posing questions with generic prompts (Chi, Bassok, Lewis, Reimann & Glaser, 1989), or following a more complicated set of scripted instructions (Rummel and Spada, 2005; Weinberger, Ertl, Fischer, & Mandl, 2005).

In summary, this section proposes that a taxonomy of a learner's overt activities (summarized in row 2 of Table 1) may be a reasonable first cut at differentiating *active* from *constructive* from *interactive* activities. *Active* activities are those that basically engage the learners' attention, such as focusing or gazing upon some aspects of the learning material, repeating the materials, or manually manipulating the presented learning materials. *Constructive* activities are those that require learners to produce some outputs, which may contained some new ideas, such as in self-explaining, drawing a concept map, or inducing hypotheses, and reflecting. *Interactive* activities involve participating in two kinds of dialogue patterns, either with experts *(instructional dialogues)* or with peers *(joint dialogues)*. Within *instructional dialogues,* learners could be participating in guided-construction activities (e.g., respond to scaffoldings & hints, revise errors from corrective feedback); and within *joint dialogues*, learners could be participating in sequential-construction or coconstruction activities (e.g., build and elaborate on a partner's contributions, argue and defend a position, criticize partner's contribution).

Three caveats need to be underscored here. First, our taxonomy classifies only overt learning activities because we can only tell that students are undertaking them if they are visible. Obviously these activities do not have to be carried out overtly. For example, one could be self-explaining covertly, as students often do spontaneously. Second, for any given activity, whether *active, constructive,* or *interactive,* they can be correctly classified to the extent that analyses of their content agree with our interpretation. This is true for all three kinds of activities. For example, an *active* activity such as *pointing* would not be engaging if a learner points at random symbols on a chalk board. Similarly, for a *constructive* activity such as self-explaining, it would not be producing new ideas if a learner self-explains primarily by paraphrasing (Teasley, 1995). Similarly, for an *interactive* activity such as dialoguing, it would not be interactive if only one of the speakers is contributing substantively. In short, these activities per se cannot be classified correctly unless some analyses of the content of the activities are undertaken. Third, nevertheless, the claim here is that the set of activities designated as *active* is more likely to engage learners than being *passive,* the set of activities designated as *constructive* is more likely to enable the generation of new ideas than the set of activities designated as *active*, and the set of dialogue activities designated as *interactive* is more likely to encourage jointly produced substantive contributions than *individual dialogue* patterns.

1.2. Underlying processes and how they can mediate learning

It is important to speculate on the underlying cognitive processes for the overt activities of *being active, constructive,* and *interactive,* in order to understand how each activity may mediate learning. Obviously the overt activities cannot accurately discriminate among the cognitive processes definitively, as it is possible that the same overt activity maps onto different cognitive processes. For example, a learner may be undertaking an activity that may look as if she is engaged (such as underlining a bolded definition in a text), but in fact she could be covertly self-explaining as well (such as thinking about how that definition conflicts with an earlier sentence). Even though the correspondence between overt activities and hypothetical cognitive processes is not perfect, postulating the potential underlying cognitive processes is nevertheless an important exercise because it may explain why one overt activity might mediate learning better than another overt activity. The hypothetical cognitive processes for each activity are discussed below and summarized in Table 1 (third row). These processes are postulated from the perspective of the learner, as opposed to the teacher or the peer, as the goal is to explain how a learner can learn from undertaking such activities.

1.2.1. Processes underlying being active

What are the cognitive processes that may correspond to *active activities* such as looking, underlining, repeating, and manipulating? Engaging in these activities may cause a learner to activate existing knowledge, search for related knowledge, or encode, store, or assimilate knowledge that is new to the learner. Thus, one can think of these processes of activating relevant knowledge, searching for related knowledge, and encoding new information by assimilating it with existing knowledge as ''attending'' processes. Why would attending processes help learning? If information is already known, then activating it can further strengthen existing knowledge, thus making it more salient, more stable, and more retrievable, thereby enhancing learning. Assimilating information that is novel to the learner also means one is adding new knowledge and perhaps filling gaps in one's knowledge base. These attending processes clearly can enhance learning as they enrich knowledge and strengthen existing knowledge, and so forth.

1.2.2. Processes underlying being constructive

What are the processes that may underlie *being constructive* in a way that generates new ideas? Constructive activities, such as self-explaining, drawing a concept map, comparing and contrasting cases, inducing hypotheses, allow the learners to infer new ideas, new insights, new conclusions, from making deductions and inductions, from reasoning analogically through comparisons, from integrating new knowledge with old knowledge, or linking information from disparate sources. In short, these various ''creating'' processes of comparing, connecting, inducing, analogizing, generalizing, etc., allow the learners not only to infer new knowledge but also to repair and improve their existing knowledge. It will also be assumed here these ''creating'' processes of *constructive* activities may necessitate the ''attending'' processes such as activate and assimilate. Thus, ''creating'' processes include ''attending'' processes.

How would these creating processes enhance learning? Inferring new relations, new conclusions, and new insights obviously makes one's knowledge more rich, and repairing one's knowledge also makes it more coherent, more accurate, and better-structured, and so forth. These changes can deepen one's understanding of new materials and have been shown to improve learning. Many of these processes have been proposed for learning from explaining-to-self (Chi, 2000) and explaining-to-other (Roscoe & Chi, 2007b).

1.2.3. Processes underlying being interactive in dialogues

As described above, individuals interacting in dialogues can participate in three types of dialogue patterns, *individual, instructional*, and *joint,* but only the latter two types are interactive. In these interactive types, the ''speaker'' learns through activities such as self-construction, guided-construction, sequential-construction, and coconstruction. Although these activities may differ in details, from the ''speaker's'' perspective, the ''speaker'' learns by being *constructive* (with cognitive processes of attending and creating).[2] Therefore, the set of processes each speaker in a dialogue might undertake is no different than the processes that a learner might undertake while *being constructive* alone. Thus, this interpretation reflects Damon's point (1991, p. 392) that ''Even when learning is fostered through processes of social communication, individual activity and reflection still play a critical role.''

That a learner in guided construction learns from *being constructive* has been shown in Chi et al. (2001, 2008) in the context of tutoring. Here, we will merely illustrate how the activities of sequential construction might enhance learning in *interaction*. In sequential construction, the partners' activities consist of building on each other's contributions sequentially. Our definition of sequential construction appears to be compatible with the majority of conceptions in the literature about collaborative construction, involving the idea of a mutual process of sequentially building on, refining, and modifying the original offer in some way (Baker, 1994). That is, each individual peer is merely creating and elaborating upon the partner's last contribution in a WIKI sort of way. This occurs sequentially with each partner taking turns building on the last contribution. Thus, making sequential contributions upon a completed prior idea is not that different from having a text as a resource for self-explaining. The difference is that a text is produced by one person and is static, whereas in sequential construction, the contributions produced by both partners change dynamically. This process may be what Salomon and Perkins (1998) might mean by ''spiral reciprocity.'' Thus, the cognitive processes of learning from sequential construction in *joint dialogues* are no different from the fundamental processes underlying *being constructive* individually.

If the processes are the same, what is the difference then between *being constructive* alone (such as learning from a text), versus *being constructive* in interaction (as in sequential construction), and how does *being interactive* contribute to learning? One fundamental difference is that in interactions, a learner has the added advantage of a partner's contributions. A partner's contributions can provide additional information, a new perspective, corrective feedback, and a new path or line of reasoning to pursue. But why do the activities of incorporating a partner's contributions enhance a ''speaker's'' learning? There are many obvious reasons. If a partner's contribution is in the form of corrective feedback, then corrective feedback in problem solving can enhance the ''speaker's'' learning by guiding the ''speaker'' through the search space, as has been shown in tutoring work (Anderson, Corbett, Koedinger, & Pelletier, 1995). A partner's contribution may also be in the form of a hint or a scaffold, which suggests to the learner to pursue a new line of reasoning, a new equation, etc. (Hume, Michael, Rovick, & Evens, 1996). A partner's contribution can also contain new information (Chi et al., 2001), so the ''speaker'' can enrich her knowledge. A partner can also challenge the ''speaker'' with a deep question (Roscoe & Chi, 2007a), causing the ''speaker'' to explore other perspectives, ones she would not have thought of herself. A partner's contribution can also remind the ''speaker'' of previously considered ideas (Azmitia, 1988).

More importantly, even though the underlying cognitive processes of sequential construction in *interactive* activities are fundamentally the same as the cognitive process of self-construction in *constructive* activity, we propose that there may be a second important difference between them, and this difference relates to the outcome of learning. In self-constructing alone with a text, the goal of the learner is to understand what the text says; therefore, the learner must construct an understanding or mental model of the text. In joint construction with a partner, the goal is to produce shared understanding or a ''shared mental model'' (Cannon-Bowers, Salas, & Converse, 1993; Jeong & Chi, 2007). This shared understanding can be achieved by sequential construction, in which each partner can change her joint understanding in a dynamic way that may result in a more innovative and novel mental model. In short, the potential outcome of this sequential construction process is the emergence of a new conception that was not available to the dyad initially. Thus, this can explain how *interactions in dialogues* can contribute to learning, in that neither of the partners may have been able to come up with the shared understanding on her own, thus by interacting, both have the potential of taking away a deeper or more novel understanding.

To summarize, interaction in dialogues can involve three types of activities: self-construction that incorporates the partner's contributions, guided construction (from interacting with an expert), sequential and/or coconstruction with a partner. In all cases, learning results from some kind of construction that the learner undertakes, either by incorporating guidance and contributions from an expert or a peer, or by taking turns in constructing sequentially with a peer, or coconstructing simultaneously with a peer.

2. A hypothesis generated from this taxonomy and evidence in support of it

The taxonomy proposed above postulates different overt activities for *being active, constructive,* and *interactive* and speculated on the hypothetical underlying processes for each of these overt activities, and how they may mediate learning. On the basis of the hypothetical underlying cognitive processes, this taxonomy can now generate a testable hypothesis, that overall, *active* is better than *passive*, *constructive* is better than *active*, and *interactive* is better than *constructive*. In all cases, the classification of *passive, active, constructive*, and *interactive* is based on the overt activities undertaken by the participants, and not the underlying cognitive processes which one cannot ascertain accurately unless a study analyzes the content of the outputs, whether they are the underlined sentences, concept maps, self-explanations, dialogues, etc. In other words, the hypothesis here suggests that *being active,* for example, is better than *being passive* or *not attentive.* For example, if a learner is reading a text and underlining, it may be reasonable to assume that the activity of underlining is more likely to engage such a student with the materials than a student who is *not* underlining therefore and being *passive.* The assumption is that a student is more likely to ''zone-out'' when passive (Smallwood, Fishman, & Schooler, 2007).

Likewise, *being constructive* is better than *being active* because *being constructive* means that a learner is creating new inferences and new connections that go beyond the information that is presented, whereas *being active* means only that old knowledge is retrieved and activated. Thus, *being constructive* subsumes *being active*.

Finally, *being interactive*, by and large, is better than *being constructive* when partners are truly interactive (as opposed to participating in self-construction only), because they can benefit from each other's contributions. This prediction is consistent with the literature on collaboration, showing that even though a majority of collaborative learning studies find learning advantages compared with individual learning, some studies do not obtain such advantages (Barron, 2003; Yetter et al., 2006). This latter finding might be explained by the fact that some dialogue patterns are in fact not interactive at all. In such cases, participating in dialogues is equivalent to self-construction alone. But on the whole, because dialoguing does result in guided construction and sequential and coconstruction types of interactions, being *interactive* might be better for learning than being *constructive* alone.

There are three ways that such a hypothesis can be tested by evidence in the literature. First, although there is no single study that can test the overall prediction, namely that *interactive* > *constructive* > *active* > *passive,* the hypothesis can still be tested by decomposing the predictions into pair-wise contrasts. A second way to test the hypothesis is to predict that if two activities are of the same kind (such as both constructive, or both interactive), then their learning outcomes should be equivalent. Finally, a third way to test the hypothesis is to select a specific activity and make predictions based on its contrasting conditions, thus potentially explaining discrepant results. For example, summarizing might be shown to be an effective activity in one study, because it is contrasted with a passive activity, whereas it may be shown to be a less effective activity in another study, because it is contrasted with an interactive activity, thus suggesting discrepant interpretation about the effectiveness of summarizing as a learning activity.

Several clarifications and caveats need to be noted in how the studies are selected below to illustrate the contrasts here, besides the fact that generally, the included studies measure learning as an outcome. First, in all the studies to be cited below, the characterization is of the activity that the student took (or presumably took) in a learning context, in terms of *passive, active, constructive,* and *interactive*. The studies themselves may be pursuing a variety of noble hypotheses, ranging from whether direct instruction is better or worse than discovery learning, to whether having a social agent is more motivating than not having a social agent, and so forth. Thus, the actual manipulations of interest in each study are ignored for the purpose here. Instead, the aim of this exercise is simply to characterize and re-interpret the manipulation of each study in terms of what activities the students took or were asked to do, to see whether they support our hypothesis.

Second, many studies are excluded because their conditions were manipulated in a fashion that may confound the prediction here. For instance, suppose that choosing an answer from a pull-down menu (*being active)* is in fact not as effective as giving an answer *(more constructive),* as predicted here. However, if the choices in the pull-down menu are so detailed, such that they actually provide extra information for the students, then obviously a pull-down menu may be more effective in this case, simply because the students had the advantage of additional content information. In essence, such a manipulation would prevent a simple interpretation or characterization of a student's activity.

Third, in a similar vein, many studies manipulate more than one activity in a given condition. Therefore, it would not be straightforward to determine what activities and processes took place and caused learning, unless such a condition is merely contrasted with a passive condition. Thus, such studies are disqualified for consideration. Fourth, when possible, only measures of deep learning are cited, since measures of shallow learning do not always discriminate among different activities. Fifth, only two examples will be cited for each pair-wise contrast to serve illustrative purposes only. This paper is not meant to be an exhaustive literature review.

Finally, the most important caveat to point out is that this hypothesis cannot be tested accurately by evidence in the literature without analyzing the actual processes a student is undertaking. Without more detailed scrutiny of the raw data of a given study, I can only make a judgment call on the underlying processes on the basis of the overt activities participants in a study are asked to perform. To determine the precise processes used in any given study would be beyond the scope of this paper.

2.1. Pair-wise contrasts

Although the overall hypothesis states that *interactive* activities are better than *constructive*, which are better than *active,* which are better than *passive,* these four cases can be compared in multiple ways, as summarized in Table 2 (the nondiagonal cells).

Table 2
Pair-wise contrasts involving comparisons between passive, active, constructive, and interactive activities

	Active	Constructive	Interactive
Passive	Note taking > No note taking (Trafton & Trickett, 2001) View with practive > View only (Schwan & Riempp, 2004)	Read & self-explain > Read twice (Chi et al., 1994) Read & self-explain > Read an elaborated text (Hausmann & VanLehn, 2007)	Assemble a plant with an animated agent > No assemble (Moreno et al., 2001) Cooperative groups > Traditional lecture (Ebert-May et al., 1997)
Active	Free form note taking = Semistructured note taking (Trafton & Trickett, 2001)	Mapping with explanation > Mapping only (Kastens & Liben, 2007) Direct instruction + reflection > Discovery learning (Klahr & Nigam, 2004)	Peer tutoring > Filling out guided notes (Mastropieri et al., 2003) Jigsaw group > Individuals gathering information (Doymus, 2008)
Constructive		Summarizing in own words = Generating questions (King, 1992)	Explaining to a partner > Explaining to no partner (Roscoe & Chi, 2007a) Learning to solve problems collaboratively with a text > Learning to solve alone with a text (Chi et al., 2008)
Interactive			Interacting with a tutor = Interactive with a peer while watching a tutor (Chi et al., 2008)

2.1.1. Active versus passive

Trafton and Trickett (2001, Exp. 1) contrasted learners who were given and encouraged to use a notepad available in the form of a blank text box interface with those who did not have a notepad. Superficially, taking notes is at minimum an *active* activity, as compared with not taking notes. However, if the notes taken were conceptual notes rather than verbatim notes, then taking notes can be considered a *constructive* activity. If students are further permitted to review their notes, then taking notes plus review (Kiewra & DuBois, 1991) definitely becomes a *constructive* activity. This illustrates the difficulty of classifying a task without analyzing the content of the notes. Nevertheless, the conservative assumption is that taking notes is an *active* activity, whereas not taking notes is a *passive activity.* The study reported results showing that learners who were given a notepad solved problems correctly 78% of the times, compared with learners who were not using the notepad, who solved the problems correctly 49% of the time. Thus, the *active* learners were significantly more successful than the *passive* learners, supporting the hypothesis proposed here.

Many studies in the literature compare *active* with *passive*. Another clear-cut example is a study in which learners are either viewing a video of tying knots while practicing tying knots (*active),* or viewing a video without the opportunity for practice (*passive).* The learners without the opportunity to practice (the passive condition) took significantly longer to learn to tie knots than the active condition (Schwan & Riempp, 2004). Similarly, in an immersive virtual-reality environment, participants who were permitted to actively rotate objects learned the object structure better than participants who passively observed the objects (James et al., 2002).

How does the *active*-is-better-than-*passive* comparison jibe with the well-known worked example effect where studying a worked-out problem solution is superior than actually solving a problem? On the surface, it seems that the more active (and perhaps constructive) activity of solving problems is worse than the more passive activity of studying examples (Sweller & Cooper, 1985). There are three resolutions to this apparent discrepancy. First, a simple characterization of *passive* or *active* cannot do justice to such a complicated study, in which the studying example condition also involves solving problems, and the problem-solving condition also includes studying examples when the solvers fail to solve them correctly. Second, if a study simply contrasts studying a worked-out solution directly with solving the same problem as the worked-out solution, then studying a worked-out solution might be superior not because it is more or less active than solving a problem, but because a worked-out solution can provide a great deal of additional information, such as how a principle is instantiated, as well as illustrate numerous other procedures (Chi et al., 1989). So this may be a case wherein the manipulation confounds a simple characterization of its activity. Third, studying examples can often be more active than it appears, as we have found that many students spontaneously self-explain while studying examples, thus making example studying a *constructive* activity rather than a *passive* activity.

2.1.2. Constructive versus passive

There are also many studies in the literature comparing *constructive* versus *passive.* The contrast is quite distinct and the results are almost always in the predicted direction. One example is a contrast between asking learners to generate their own explanations as in self-explaining, compared with learners who read the same text twice (Chi et al., 1994), in order to equate time-on-task. Assuming that learners who read the text twice were more *passive*, whereas self-explaining is a *constructive* activity, it is not surprising that the condition that required students to self-explain had better learning outcomes. A more stringent test of the above comparison is to ask students to self-explain an incomplete example versus to paraphrase a complete example that incorporated all the inferences and integrations that self-explainers should generate on their own (Hausmann & VanLehn, 2007). Again, the self-explaining condition (*constructive*) had better learning outcomes than the paraphrase condition (*active*).

Many other studies have made similar contrasts, such as between self-explaining (*constructive)* and not self-explaining (*passive),* in the context of a WEB-enabled tutor. Self-explaining is better for both problem-solving performance and understanding of the domain (Mitrovic, 2005).

2.1.3. Interactive versus passive

One example of comparing an *interactive* condition with a *passive* condition is the availability of an animated agent. In a study by Moreno, Mayer, Spires, and Lester (2001, Exp. 1), one condition (Plant Assembly condition) consisted of interacting with a multimedia program called Design-A-Plant. This program included a pedagogic agent who gives advice to learners as they assembled plants from a library of plant parts (roots, stems, leaves). Learners in the NO Plant Assemble condition did not have the opportunity to assemble any plants, even though the material was explained to them directly. Thus, one could interpret these two conditions to be *interactive* versus *passive.* Looking at the deeper measure of transfer (versus retention), the Plant Assemble group produced significantly more correct solutions on transfer problems than the No Plant Assemble group. However, the two groups did not differ in the more shallow retention test.

Another example of comparing *interactive* with *passive* is a study that compared a cooperative condition in which students were assigned to cooperative groups, and moreover, engaged in five phases of interactive dialogues, including explaining and elaborating, with a more passive condition in which students listened to a traditional lecture in which the instructor talked and the students listened. The *interactive* group outperformed the *passive* group (Ebert-May, Brewer, & Allred, 1997). Although this study manipulated many variables in the cooperative group condition as compared to the lecture condition, the point remains that when students are asked to explain and elaborate in group discussions, such activities are more *interactive* than a condition in which students merely sat there *passively* and listened to a lecture.

2.1.4. Constructive versus active

According to the proposed hypothesis, learning outcomes of *constructive* activity should be better than learning outcomes of an *active* activity. One example of such a contrast is to compare an explaining condition in which fourth-grade students had to write down and explain what clues they used in a field-based map skills task, with a baseline condition in which they were required to place flag stickers to correspond to flags on a model map without explaining. The explainers (*constructive)* were clearly superior in performing this task than the students who simply placed the flags (*active)* without explaining (Kastens & Liben, 2007).

For a second example, the contrast is between direct instruction and discovery learning. In the discover condition, Klahr and Nigam (2004) asked third- and fourth-grade students to discover on their own the control-of-variable strategy (CVS) by designing experiments using an apparatus for which they could manipulate the steepness, length, and surface of ramps, to see how far a ball would roll. In the direct instruction condition, children observed as the experimenter designed several experiments to determine the effects of the variables such as steepness and run length. This is considered a direct instruction condition because the experimenter also explained why each of the experiments uniquely identified the factor that determined the outcome. Klahr and Nigam emphasized that both groups of children were active in that they both had opportunities to engage in the design of experiments and physically manipulate the apparatus.

The direct instruction group outperformed the discovery group (presumably more *constructive)* significantly in deep learning assessments. It may appear surprising that the direct instruction group (presumably only *active* from physically manipulating the apparatus) outperformed the discovery group (presumably more *constructive*), since as noted early on in this paper, the term ''discovery learning'' is used in the literature to imply *constructive* learning, and direct instruction implies more *passive* form of learning as in *instructionism*. However, upon closer scrutiny, the direct instruction group was further told to determine ''whether or not they thought the design would allow them to 'tell for sure' whether a variable had an effect on the outcome,'' after seeing the result of an experimenter-designed experiment. Given that reflection and self-explaining are fairly powerful constructive activities, asking students to reflect so that they can ''tell for sure'' makes the direct instruction condition into a *constructive* one, whereas the discovery condition can be considered only an *active* one if the students did not discover many of the rules. In short, it makes sense that the *constructive* (direct instruction) condition is better than the *active* (discovery) condition. This is a good example of a study in which a closer scrutiny of the procedure allowed me to reinterpret the results in terms of the taxonomy proposed here.

2.1.5. Interactive versus active

A clear example of being *interactive* versus *active* is a study comparing students who participated in reciprocal peer tutoring with students who participated in filling out guided notes. The guided notes were constructed by the teacher and consisted of fill-in-the blank items, matching items, vocabulary, and short-answer items. Basically these test items had answers that were easy to find, so that finding the answers constituted an *active* activity. Peer tutoring is obviously an *interactive* activity. Not surprisingly, peer tutoring was significantly better than filling guided notes (Mastropieri, Scruggs, Spencer, & Fontana, 2003).

A second example is a study in which students were learning the concept of chemical equilibrium either in jigsaw groups or alone. In the jigsaw context, each individual student had to become an expert in some aspect of the concept, then moved into groups wherein each expert took turn teaching the other members of their group who were nonexperts. Thus, this condition clearly qualifies the students to be engaged in an *interactive* activity. For the individual learning condition, the students were provided with Internet addresses and workbooks from which they were to gather information relevant to the concept. This might be classified as an *active* activity. Students in the jigsaw *(interactive)* group learned more than the students in the gather information individually *(active)* group (Doymus, 2008).

2.1.6. Interactive versus constructive

One example of a contrast between *interactive* and *constructive* is our study that compared how a student learned from explaining to a partner versus explaining to no one, after studying a text passage about the eye (Roscoe & Chi, 2007a). Students in the partner condition were told to explain beyond what the text said and to help the listening partner really understand. These explainers were encouraged to answer their partners' questions, which gave them opportunities to be *interactive*. Students in the no-partner condition were told to produce a lesson (that was tape recorded) that could be used by another student later to learn from their explanations of the material. Thus, the no-partner explaining group is constructive in that explaining in a lecture kind of scenario does require the explainers to create organization for the materials, to learn more deeply so they can explain, and so forth. The results showed that the explainers in the partner condition (*interactive)* were slightly but consistently better than the explainers in the no-partner condition (*constructive*). How does having a partner help?

The listening partners in the explaining-to-a-partner condition were ''ignorant'' in the sense that they were not given the opportunity to learn the materials from the text a priori. Only the explainers in this partner condition were given the privilege of learning the materials prior to explaining; therefore, the explainers took on the role of a knowledgeable peer tutor. It seems counterintuitive that ignorant listening partners can promote more learning in the explainers. To understand the contribution of an ignorant partner, we transcribed and segmented explaining protocols of all three conditions into ''episodes.'' An ''episode'' was segmented in much the same way as in Chi et al. (2008), except instead of explanations devoted to a problem-solving step, an episode here consists of explanations about a single topic, such as an eye component. For each episode, we coded whether it is a ''knowledge-telling'' kind (Scardamalia & Bereiter, 1987) or a ''knowledge-building'' kind. A ''knowledge-telling'' episode consists of unelaborated summaries and paraphrases of the text information, whereas a ''knowledge-building'' episode consists of integration of concepts and generation of inferences. Not surprisingly then, ''knowledge-building'' episodes, being more *constructive* by our coding definition, correlated significantly with deep posttest scores ($p < .01$), whereas ''knowledge-telling'' episodes, being more *active,* correlated somewhat negatively (but not significantly) with deep posttest scores.

What is surprising are the following two results. First, not only did the listening partners generated a huge number of questions (a total of 310 questions were generated across the 10 listening partners), but over one-third (37%) of the questions can be classified as deep questions. The advantage of deep questions over shallow questions is that deep questions were more likely to elicit both deep responses as well as metacognitive responses from the explainers, both kind of responses correlated with the explainers' learning (see Table 3 in Roscoe & Chi, 2007a). Second, the episodes can be further coded as being either ''partner-initiated'' or ''explainer-initiated,'' depending on who chose the concept, who asked a question, or made some comments changing the topic to be discussed. Although the literature consistently shows that tutors tend to dominate the tutoring dialogues, what is surprising in this analysis is that the listening partners initiated more knowledge-building episodes (62.1%) than knowledge-telling episodes (26.2%), whereas the explaining tutors initiated more knowledge-telling episodes (73.9%) than knowledge-building episodes (37.9%).

In sum, these two fine-grained analyses show the surprising results that interacting even with an ignorant partner has significant advantages for the explainer, in that it can cause the explainer to answer questions deeply, and it can cause the explainer to engage in more knowledge-building activities. Thus, a real partner, even if she is ignorant, can ask deep questions and take other initiatives that may push the explainer to explain, thereby learn more. Without the active-constructive-interactive taxonomy, these particular results would have appeared nonintuitive, in that the common assumption is that crafting effective explanations with the goal of producing a lesson (in the no-partner condition) should have been a very demanding constructive activity, as in preparing a lecture for a large classroom that affords no interaction opportunities with the audience. However, our results show the additional advantage of *interaction* in that having a listening partner can foster greater learning in the explainer because their interactions can shape and challenge the explainer to learn more. This study also illustrates the benefit and need to scrutinize more closely what processes were actually undertaken in a given condition. Because this is our own study, we have the opportunity to code and understand the processes that may underlie a specific condition, and thereby we can more accurately classify a condition or explain its effects.

A second example of *interactive* being better than *constructive* can be seen in the results reported in Chi et al. (2008) in which we compared learning to solve problems collaboratively with a text *(interactive)*, with learning to solve problems alone with the same text *(constructive)*. The problem-solving activity is included in the learning phase here because the learners were in fact asked to try and solve three problems while studying the text. They were also asked to solve problems after they have learned from the text, but here we are classifying the conditions on the basis of what they did while learning. Learners in the collaborative learning condition (*interactive)* solved significantly more problems correctly than learners in the alone (*constructive*) condition ($F(1,28) = 6.442$, $p = .017$, $d = .425$), although this difference was not reported in Chi et al. (2008).

In summary, this section compares studies that contrast one kind of activity with another kind. In general, these studies in the literature confirm our hypothesis that the direction of learning gains for the contrasting conditions is as predicted by the taxonomy.

2.2. *Equivalent outcomes*

The taxonomy proposed here should also predict equivalent learning outcomes for activities of the same kind. That is, activities that are both *active*, or both *constructive,* or both *interactive*, should produce largely the same learning outcomes, barring any additional manipulations to one versus the other. Below, one example is given for each comparison of equivalent kinds.

2.2.1. *Active versus active*

Taking notes in free form versus taking notes in a semistructured form are both *active* activities, assuming that neither set of notes was particularly elaborative (Trafton & Trickett, 2001). The results, not surprisingly, show equivalent learning.

2.2.2. *Constructive versus constructive*

If students are asked to summarize ideas from a lecture in a way that linked them together using only their own words, then this type of summarizing can be considered a kind of *constructive* activity since in linking information together using their own words, students may create new knowledge. Similarly, if students are asked to generate questions to themselves using question stems to create ''think type'' questions, then generating questions is definitely a *constructive* activity. Therefore, it is of no surprise that there is no difference in learning from these two types of *constructive* activities (King, 1992).

2.2.3. Interactive versus interactive

Interacting with a tutor and interacting with a peer while watching a video of tutoring are both *interactive* activities in that students in both groups can participate in dialogues, even though in the tutoring condition the student gets to converse directly with a tutor and in the observing condition the students get to converse with a peer (but not with a tutor). Therefore, the two groups did not differ in their learning gains, adjusted for their pretest scores (Chi et al., 2008). Again, without this active-constructive-interactive taxonomy, such results would have been really surprising given that the assumption in the literature is that individualized tutoring is an excellent way to learn because the tutor is tailoring her guidance to the tutee. In this case, the observers learned just as much even though they did not benefit from the tutor's guidance but merely watched the tutor guide another tutee in the videotape. The observers must have benefited from their interactions with a peer.

In short, this section suggests that if one were to compare learning activities of the same kind, then the active-constructive-interactive framework predicts that there should be no learning differences. This prediction has an important implication for research results that claim one activity is better than another activity when the comparison is between kinds. Thus, in order to claim that one learning activity is better than another, researchers will need to use a control condition that tests activity of the same kind. (All the pair-wise comparisons are shown in the diagonal cells of Table 2.)

2.3. Context of comparison

A third way to test the taxonomy presented here is in terms of how a given activity is carried out as well as what other activity it is compared with. The first point can be illustrated as follows. Summarizing can be carried out in a copy-and-delete way, in which a summary is produced by deleting details and irrelevant information and rephrasing what was stated in the materials without adding any new inferences (Brown & Day, 1983). This type of summarizing might be considered an *active* activity. On the other hand, students can also be instructed to summarize in a much more *constructive* way, such as identifying the main topic and subtopics of a lecture, then creating a sentence to reflect that topic, and writing sentences to link subtopics to each other in their own words, and so forth (King, 1992). One would predict that this *constructive* kind of summarizing would be better for learning than the *active* kind. Although there may not be a study that directly compares the two kinds of summarizing activities, there are studies comparing and showing that the copy-and-delete kind of *active* summarizing is better than a more *passive* activity of listening to a partner's summary (Coleman, Brown, & Rivkin, 1997), whereas the more *constructive* type of summarizing requiring creating sentences to link to topics and subtopic is as effective as other *constructive* activity such as self-questioning (King, 1992). These results are consistent with the prediction here. Thus, one cannot rely on a general description of an activity to conclude whether it is an effective learning activity.

Similarly, as another example, there are a variety of ways that students can take notes. If a student is taking notes in either a verbatim way, or uses a copy-and-paste function in a word processing system, or merely underlining (Ayer & Milson,1993), or selecting notes from a pop-up menu, then this sort of note-taking is an *active* activity in that very little inferences or new information is generated while taking notes. However, students can also take more conceptual notes, such as in a self-questioning manner. In such a case, taking notes would be a *constructive* activity since their notes may create new knowledge. Not surprisingly then, taking notes in a self-questioning manner is better than copying verbatim (Shimmerlik & Nolan, 1976; Spires, 1993). Thus, studies on the benefit or limitation of a given learning activity must be interpreted in the context of how the activity was carried out by the students.

The second point about context of comparison refers to the condition with which a specific activity is contrasted. That is, whether a specific learning activity will show benefit or not depends on its contrasting condition. Although self-explaining may be a powerful *constructive* activity, it may not be as powerful as jointly explaining with a partner, an *interactive* activity. There is suggestive evidence that jointly explaining either with an expert (Chi et al., 2008) or with a peer (Hausmann & VanLehn, 2007) is more beneficial to learning than self-explaining alone. However, self-explaining, a *constructive* activity, might be better for learning when compared to an *active* activity such as selecting an explanation from a menu (Corbett, Wagner, Lesgold, Ulrich, & Stevens, 2006). Similarly, a *constructive* activity such as compare-and-contrast in which students are asked to consider the similarities and differences between two cases, in conjunction with listening to a lecture, has been shown to be more effective than listening to a lecture only (a more *passive* activity; Schwartz & Bransford, 1998). However, compare-and-contrast is only slightly more effective than self-explaining, both being *constructive* activities (Gadgil & Chi, unpublished data).

In short, whether an activity is claimed to be an effective learning strategy must be evaluated in the context of both the specifics of how an activity is being carried out and thus its potential underlying processes, and its comparison condition. These two context considerations can often offer explanations for results that might appear discrepant in the literature or contradict our taxonomy.

3. Discussion

This paper provides a framework for understanding and interpreting many results in the literature with respect to learner activities that might be considered *active, constructive,* and *interactive.* The framework consists of a taxonomy that generates a hypothesis, that *interactive* activities might be better than *constructive* activities, which in turn might be better than *active* activities, which would be better than *passive* activities. This hypothesis is generated from the potential differences in the underlying processes that might mediate learning in each kind of activities. The hypothesis is tested by interpreting results in the literature in three ways: by comparing contrasting conditions of different kinds of activities, by comparing similar kind of activities, and by comparing a specific activity in the context of how it is carried out as well as in the context of its comparison conditions. This last point is particularly important, in that it emphasizes the fact that researchers cannot claim that a specific activity is beneficial unless it is compared with another activity of the same kind.

This active-constructive-interactive framework is therefore learner-centered, in that it delineates learning outcomes as a function of the kind of activities undertaken by the learners. The framework basically offers a way to differentiate *active* from *constructive* from *interactive*, in terms of overt activities and their corresponding underlying processes that may mediate learning. The framework can also offer a way to understand and interpret many results in the literature, including discrepant ones. Unfortunately, many intervention studies in the literature cannot be interpreted clearly in terms of which kind of activities it is proposing, unless the study also analyzes the processes underlying the activities, of how an activity is being carried out.

The framework differs from other frameworks in emphasis and outcomes. For example, the cognitive load theory emphasizes the prescription of certain principles for how learning *materials* ought to be designed as its outcome (Pass, Renkl, & Sweller, 2004). Because of the limited capacity of the modality-specific stores in working memory, the cognitive load theory would prescribe presenting materials in both visual and textual modalities (Mayer, 2001). In contrast, the proposed active-constructive-interactive framework focuses on understanding how different learning *activities* can benefit or foster learning. Therefore, this framework is more appropriate for analyzing whether a learning activity is an *active, constructive,* or *interactive* kind and predicting its learning outcome, with only suggestions for how a particular learner activity can be elicited. However, both the cognitive load theory and the current framework postulate hypothetical cognitive processes as a way to understand how they may mediate learning. And they are complementary in that a cognitive load approach can always further reduce memory load and thereby enhance the learning outcome of any activity, whether it is *active, constructive,* or *interactive.*

Even with explicit identification of overt activities, suggesting ways to elicit a specific desired activity remains challenging. For example, we attempted to elicit self-explanations using a typing response (Hausmann & Chi, 2002). But because the typed responses were recorded, students were reluctant to generate the spoken type of self-explanations, such as self-explanations that were fragmented, incomplete ideas, minute inferences, and so on (Chi et al., 1994). Instead, students took a conservative approach and basically copied by typing the materials presented in a computer interface. Likewise, in another study, we wanted to compare critical discussion with elaborative discussion by peers (Hausmann & Chi, unpublished data). We asked students to challenge and criticize each other in one condition, and build and elaborate on each other's contributions in another. Although students were happy to elaborate on each other's contributions, resulting in greater learning, they were hesitant to criticize each other, as revealed after a content analysis of their discussion, and consistent with the results of Baker, de Vries, Lund, and Quignard (2001). In short, many pitfalls and challenges remain in designing ways to elicit a specific activity. Nevertheless, presenting a specific conceptual framework might enable researchers to design better elicitation methods, better comparison conditions, and more meaningful interpretations of their results.

Notes

1. Note that a video is a dynamic presentation, so watching it without exploring it or manipulating it actively seems to be more *passive* than searching and focusing on a specific location of a static chessboard, which is considered an *active* activity.
2. In *individual dialogues*, if the two partners have complementary knowledge and take turns in assuming the ''explainer or speaker'' role, then both partners will learn, but each partner learns when she is explaining. Several studies have shown that the ''speaker'' who takes the explaining role learns more than the partner who takes the ''listener'' role (Coleman et al., 1997; Hausmann, Chi, & Roy, 2004; Schwartz & Bransford, 1998). This is because the ''speaker'' is being *constructive*, whereas the ''listener'' may only be *attentive*.

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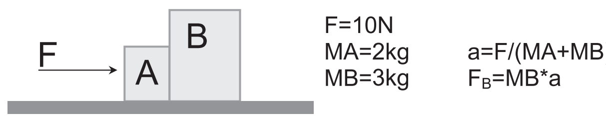
Appendix A: Self-construction activities in *individual dialogues*

Individual dialogues occur when a speaking partner is either explaining-to-self or explaining-to-other. In the context of collaboratively solving a physics problem, explaining-to-self is the case in which the speaking partner attempts to solve the problem himself and self-explains as he works the problem, while ignoring the partner. See the figure below for an example of a dialogue segment in which ''Steve'' is basically doing most of the work and explaining to himself. ''Steve'' is ignoring ''Andy'' either because ''Andy'' does not take many turns, or when he does, his contributions are not substantive. Explaining-to-self can be easily recognized by coding just one person's contribution to see if it follows a line of reasoning without adding any contribution from the partner. If so, then the peer is self-explaining or reasoning on his own, and either ignores the other partner's contribution, or the partner is not making any substantive contributions.

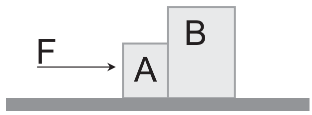


Steve:	Force acting on B would be accel-uh two, meters per second squared, but it's not in newtons. Force is in newtons. [Steve writes ''2 m/s^2 = '']
Steve:	Equals, M of B, [Steve writes ''MB'' after the=] times a. [Steve finishes equation so it reads ''2 m/s^2 = MBa'']
Steve:	So, [Steve writes ''2 m/s^2 = 3 kg'']
Steve:	Wait. What are /we supposed to be finding?
Andy:	/Force-we're doing force of B.
Steve:	Ok.
Steve:	Ok. We can't do what I said though, because, the net-I'm already saying that acceleration we found was, the net force acting on B, which would be two meters-we wouldn't be figuring anything out if we just-
Andy:	Ok. Well then let's-let's scratch that then.

These are fictitious names but the protocols are taken from data collected in Chi et al. (2008), from the Collaborating condition, in which peers are collaboratively trying to solve a ''compound body'' problem in physics.

On the other hand, there are *individual dialogues* where a ''speaker'' is explaining-to-other, as when a ''speaker'' thinks she understands a concept or problem better than her partner and attempts to explain or teach it to her partner. Explaining-to-other may start with answering a partner's question, then continuing with more explanations. Basically the ''speaker'' takes the role of a teacher or tutor. Using the same collaborative problem-solving context, the figure below is an example that we might consider explaining-to-other, in which ''Beth'' is explaining to ''Abbey.'' It can be distinguished from explaining-to-self in that the explainer sometimes monitors the listener's understanding and responds to the listener's questions. Explaining-to-other occurs often in cooperative dialogues in which each partner has unique expertise (Ploetzner, Dillenbourg, Praier, & Traum,1999) or in reciprocal peer tutoring (Fuchs, Fuchs, Bentz, Phillips, & Hamlett, 1994).

Although the distinction between explaining-to-self versus explaining-to-other is subtle, it actually can be differentiated by several cues. An explicit cue that we had used to differentiate the two kind of explanations is whether we know for a fact that the explaining student knows or understands the concept a priori, as assessed by a pretest. If a student knew the concept on the pretest, then we are more confident in coding the dialogues as one involving explaining-to-other (Hausmann et al., 2004).



Beth:	So like 14 newtons would be the net force acting on B?
Abby:	No, this-the overall force is ten,
Beth:	Mm-hmm.
Abby:	but if you split it, if-if-both of the blocks, as we know, are accelerating at two meters per second. If they're in contact then they have to be accelerating at the same, rate.
Beth:	Mm-hmm.
Abby:	And, because, by Newton's second law F-F [pause] equals mass times acceleration. And we know the acceleration,
Beth:	Mm-hmm.
Abby:	of each block and we know the mass of each block. So you can calculate the force-the force of each block. Or the force acting on each block.

Source: Hausmann et al. (2004).

Whether explaining-to-self or teach-partner, the ''speaker'' in individual dialogues dominates the conversation for a given coding episode (or a segment of dialogues). Such dominance can rotate between the partners in a cooperative and reciprocal way. The ''speaker's'' activities of explaining-to-self and explaining-to-other in *individual dialogues* will be referred to as self-construction activities. These activities are *constructive* to the extent that they have created new ideas and inferences.