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# USING GENERIC AND CONTEXT-SPECIFIC SCAFFOLDING TO SUPPORT AUTHENTIC SCIENCE INQUIRY

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**ABSTRACT**

In this conceptual paper, we propose an heuristic to balance context-specific and generic scaffolding, as well as computer-based and teacher scaffolding, during instruction centered on authentic, scientific problems. This paper is novel in that many researchers ask a dichotomous question of whether generic or context-specific scaffolding is best, and fail to focus on what processes and cognitions each type of scaffolding excels at supporting. To arrive at the heuristic and construct the framework, we synthesized research on (a) student challenges gaining and using scientific reasoning strategies, and (b) computer-based and teacher scaffolding.

**KEYWORDS**

Scaffolding; generic support; context-specific support; authentic inquiry

## 1. INTRODUCTION

When appropriately deployed, scaffolding can play an important role in supporting higher-order thinking (Reiser, 2004; Wood et al., 1976). While most researchers agree that both teacher and computer-based scaffolding is needed (McNeill and Krajcik, 2009; Saye and Brush, 2002), there is little agreement on how to effectively balance these two types of scaffolding (McNeill and Krajcik, 2009). Furthermore, scaffolding can be either context-specific or generic, yet little research addresses when and why each type of scaffolding should be used (Belland, In press). In this conceptual paper, we propose an heuristic to balance context-specific and generic scaffolding, as well as computer-based and teacher scaffolding, during instruction centered on authentic, scientific problems. This heuristic was developed through synthesis of research on (a) student challenges learning and using scientific reasoning strategies, and (b) computer-based and teacher scaffolding. This paper is important because many researchers fail to focus on the processes and cognitions each type of scaffolding excels at supporting. Scaffold designers may find this paper useful as they design technology-enhanced learning environments and work with teachers to facilitate student use of such.

This paper is organized as such: First, to provide context for the skills that scaffolding supports, we discuss authenticity in education. Then, we explore the nature of scientific reasoning, and the extent to which it employs context-specific and generic skills. Next, we define and discuss scaffolding and discuss research-based strategies for balancing different scaffolding types. Last, we mention remaining questions and suggestions for future research.

## 2. AUTHENTICITY IN EDUCATION

### 2.1 What Tasks have the Potential to be Authentic

According to canonical authenticity, educators interested in providing authentic experiences simply need to determine who the professionals are in the target domain, what they do (both mental and physical processes), and have students do the same thing.

However, this view is problematic for several reasons. First, recent research indicates that it is unrealistic to expect students to carry out the same research that a professional scientist would, because there is too much knowledge, skill, and expensive equipment required to do so (Chinn and Malhotra, 2002). But it may be reasonable to expect students to carry out somewhat simplified tasks that involve similar epistemic processes (Chinn and Malhotra, 2002; Lee and Songer, 2003). Next, science always happens in a cultural context (Barab et al., 2000; Hung and Chen, 2007). This cultural context contains colleagues and the theoretical stances they take, and the theoretical stances the individual scientist takes. This influences what questions are addressed and how, and how the resulting data are interpreted (Kuhn, 1996; Nersessian, 2008). Last, what teachers, students, and professionals see as authentic are not always the same (Barab et al., 2000; Nason and Woodruff, 2003). Students can see activities as authentic if they think the skills being learned can be applied in their lives (Barab et al., 2000). Not all middle school students intend to become scientists when they grow up, but they are all citizens who will need to make informed decisions on scientific issues (e.g., climate change or local pollution).

### 2.2 Manner in which Authenticity is Established

In the traditional view of authenticity, one simply needed to package what professionals do in the real world, bring it back to the classroom, and students would recognize that what they have in front of themselves is authentic (Barab et al., 2000; Rahm et al., 2003). Two recent ideas have emerged for how to establish authenticity. First, by working alongside professional scientists, students interact with scientists as scientists interact with each other, and in turn see that they are engaging in authentic science (Hung and Chen, 2007). But this approach presents some challenges. The job descriptions of professional scientists usually do not involve helping K-12 students as apprentices (Barab et al., 2000). Also, it is challenging to get professional scientists and students in the same place. Second, students may be able to perceive authenticity through negotiation of project parameters with other students and teachers (Barab et al., 2000; Rahm et al., 2003). One issue with this approach is that teachers and students often have misconceptions about how scientific ideas are developed and established (Rahm et al., 2003). This may be addressed through use of augmenting persons (i.e., target professionals) who can interact with the class for part of the unit (Hung and Chen, 2007).

## 3. SCIENTIFIC REASONING

Scientific reasoning involves addressing questions about the natural world with data, rational reasoning from prior knowledge, or a combination of both (Giere, 1990; Nersessian, 2008; Schunn and Anderson, 1999). It is important to consider the roles of data, domain-specific conceptual knowledge, domain-general reasoning strategies, and domain-specific reasoning strategies in scientific reasoning.

### 3.1 Data in Scientific Reasoning

To move from explanations of one isolated incident to theories that explain and predict a larger range of phenomena, it is important to integrate research findings of many scientists through argumentation (Osborne, 2010). When constructing arguments, one needs to (a) make a claim that is supported by the preponderance of data, (b) present support for the claim, and (c) revisit the claim in light of additional evidence and critiques (Ford, 2012; Perelman and Olbrechts-Tyteca, 1958).

### 3.2 Domain-specific Conceptual Knowledge in Scientific Reasoning

Domain-specific conceptual knowledge is important in that it can help scientists determine the relevance of and how to interpret particular data (Brand-Gruwel and Stadtler, 2011; Smith, 2002). For example, a physician who is trying to diagnose the cause of muscle spasms in a patient's leg would draw on content knowledge about physiology and muscle structure in the course of diagnosis. However, the diagnosis strategy would share much with that used by a mechanic diagnosing a transmission problem (Smith, 2002).

## 3.3 Domain-general and Domain-specific Skills in Scientific Reasoning

The idea of domain-general reasoning strategies has received much criticism in recent years, in part due to the practice of developing problem solving heuristics from studying people solving well-structured problems (e.g., Towers of Hanoi) in laboratory settings (Perkins and Salomon, 1989). Many authors in turn argued that most scientific problem solving is domain-specific. However, recent research indicates that scientific reasoning cannot be fully explained by domain-specific reasoning strategies (Abd-El-Khalick, 2012; Schunn and Anderson, 1999; Smith, 2002). In fact, scientific problem solving often involves a mix of domain-specific and generic skills (Abd-El-Khalick, 2012; Jonassen, 2011; Lawson, 2010). Domain-specific skills often predominate when scientists encounter problems that are similar to those encountered in the past, whereas domain-general skills predominate when scientists encounter novel problems (Roberts, 2007).

It is unwise to consider thinking skills as general across tasks; rather, thinking skills can be thought of as general across domains when engaging in similar tasks (Jonassen, 2011; Smith, 2002). Problem types range from the most well-structured (story problems) to the most ill-structured (design problems) (Jonassen, 2011). For example, troubleshooting a water quality problem and fixing a leaky roof may involve many of the same strategies. But troubleshooting problems and designing experiments in water quality analysis likely share few reasoning strategies.

Domain-general strategies include (a) thinking dispositions such as thinking planfully and being curious, (b) basic thinking techniques, such as problem solving and evaluation strategies, (c) tool use, such as brainstorming, concept mapping, and systems thinking, and (d) process-specific thinking skills, such as negotiation (Perkins, 1995).

Domain-specific knowledge and skills - declarative knowledge, concepts, and problem solving strategies - are needed in scientific problem solving. Domain-specific skills include (a) field-specific thinking skills, such as the differing ways evidence is used in law versus fine arts, and (b) situation-specific thinking skills (Perkins, 1995). Greater command of domain-specific declarative knowledge and concepts makes it easier to constrain the problem space (Duncan, 2007). For example, when creating a model of a river ecosystem, it is helpful to know what insects, fish and plants typically live in the river, what insects the fish eat, what insects cut up leaves, and what insects are most sensitive to pollution (Duncan, 2007).

# 4. SCAFFOLDING

## 4.1 Original Conceptualization

In its original conceptualization, scaffolding referred to dynamic support provided by a teacher or a parent that allowed a child to engage in a task that he/she could not complete without assistance (Belland, In press; Wood et al., 1976). This process involves "(a) enlisting student interest, (b) controlling frustration, (c) providing feedback, (d) indicating important task/problem elements to consider, (e) modeling expert processes, and (f) questioning" (Belland, In press). Scaffolding today includes three variations – one-to-one, computer-based, and peer (Belland, In press) – of which two will be explained in this paper.

## 4.2 One-to-one Scaffolding

One-to-one scaffolding follows the original definition of scaffolding in that it relies on dynamic assessment, provision of just the right amount of support, and fading of the support (van de Pol et al., 2010). But it varies in that the typical K-12 classroom setting has about 30 students and one teacher (Belland, 2012). This makes one teacher incapable of providing all scaffolding support that her students need (Saye and Brush, 2002). Teachers can provide support that is context-specific or generic according to what dynamic assessment indicates that the student needs at that point in the unit. In the literature, one-to-one scaffolding most often employs questioning, modeling expert processes, and providing feedback (Belland, In press). This works well in assessing the clarity of and helping students improve articulated ideas (Jadallah et al., 2010; Maloch, 2002). As dynamic assessment indicates that students gained skill, scaffolding support can be reduced until students can complete the scaffolded task independently (Collins et al., 1989; Wood et al., 1976).

## 4.3 Computer-based Scaffolding

Computer-based scaffolding can be designed to serve many of the same functions as one-to-one scaffolding. However, computer-based scaffolding is not generated on the basis of dynamic assessment, but rather based on an analysis of projected student difficulties (Belland, In press). Scaffolding should serve to (a) structure tasks through simplification and guidance, and (b) highlight particularly important aspects of the learning task. This support can be either generic or context-specific (Reiser, 2004). Such scaffolding often leads to desirable outcomes such as evaluation using epistemic terms (Sandoval and Reiser, 2004) and effective integration of ideas with groupmates (Gijlers et al., 2009).

Generic scaffolds can be helpful in structuring the overall process (Belland, 2010; Reiser, 2004) and encouraging students to be reflective in their work (Davis, 2003). For example, while preparing a science news story, middle school students were exposed to generic prompts that encouraged them to "stop and think" (Davis, 2003, p. 92). Davis (2003) found that high autonomy students performed better with generic scaffolds than low-autonomy students. As another example, high school students use the *Collaborative Concept Mapping Tool* to collaboratively create a model of a problem using concept mapping (Gijlers et al., 2009). Students who used this tool engaged in more detailed conversations aimed at integrating their ideas than students using a context-specific scaffold (Gijlers et al., 2009).

Context-specific scaffolds tailor scaffolding support to particular content. For example, *ExplanationConstructor* asks students questions related to the evolution of finches on the Galapagos Islands (Sandoval and Reiser, 2004). In the *How Do We Make New Stuff from Old Stuff* unit, context-specific scaffolds gave middle school students step-by-step instructions for what they needed to do (McNeill and Krajcik, 2009). Students who received context-specific computer-based scaffolds and generic one-to-one scaffolding wrote better scientific explanations than students who received generic computer-based scaffolding and context-specific one-to-one scaffolding (McNeill and Krajcik, 2009).

## 4.4 Mixing Generic and Context-Specific Scaffolding

One should not ask whether to use generic *or* context-specific scaffolding in supporting students' scientific reasoning, but rather, one should ask what is the right mix between the two types of scaffolds (Abrami et al., 2008). Given that K-12 students need both one-to-one and computer-based scaffolding (McNeill and Krajcik, 2009; Saye and Brush, 2002), and also strengthening in both domain-specific and domain-general skills (Schunn and Anderson, 1999), one can consider having some scaffolding be context-specific and some generic. There is limited research on what mix of generic and context-specific scaffolding works best (Belland, In press). In the context of the McNeill and Krajcik (2009) study, evidence was found that having context-specific computer-based scaffolds and generic one-to-one scaffolding worked the best. But it must be noted that the finding is related to one study in one context, and further research is needed in other contexts.

Factors considered in this section include research on authenticity in education and scientific reasoning, and what one-to-one and computer-based, as well as generic and context-specific scaffolding, support best.

### 4.4.1 Authenticity in Education Considerations

One problem with developing context-specific computer-based scaffolding is that it relies to a large extent on pre-packaging authenticity. This is because computer-based scaffolding needs to be created prior to student engagement with the unit. While one may be able to identify and embed some domain-specific processes by which professional scientists engage in science, one would not be able to embed all such processes. Science is not a static field, and depending on the perspective that a scientist brings, many reasonable approaches can be taken when solving a given problem (Sarkar, 2007). And embedding the social context is very difficult. Given that computer-based scaffolds are developed prior to student engagement in the problem, only pre-selected strategies could be embedded into computer-based scaffolds.

Embedding context-specific support in computer-based scaffolds is also limiting in that if particular students do not perceive the target problem as authentic, then there are two possibilities: (a) the computer-based scaffolds are used and the unit is not perceived as authentic, or (b) a new unit needs to be developed that the target students can perceive as authentic and other computer-based scaffolds need to be identified or developed. Generic computer-based scaffolds can be used with a variety of units such that a problem that target students can perceive as authentic can be selected/developed.

### 4.4.2 Scientific Reasoning Considerations

To determine what scaffolding can be context-specific and what scaffolding should be domain general, it is important to think about the type of domain-general and domain-specific skills involved in scientific problem solving. The main domain-specific skills include methods of thinking specific to particular domains and contextual modes of thinking (Perkins, 1995).

But at the same time, students need context-specific scaffolding support, especially to learn contextual cues related to the target problem. Such support can be provided through one-to-one scaffolding. With one-to-one scaffolding, one does not need to prepackage authenticity, and can give just the right amount of context-specific support, as it is needed. Augmenting persons can help the teacher provide one-to-one scaffolding for part of the unit (Hung and Chen, 2007).

### 4.4.3 Proposed Approach

One does not need to make all one-to-one scaffolding generic or context-specific, and do the same with computer-based scaffolding. Rather, one can consider whether one-to-one or computer-based, and generic or context-specific support may be most appropriate for each major area in which students need scaffolding support. One can also use augmenting persons - professional scientists - who can provide some one-to-one scaffolding support when they visit the classroom (Hung and Chen, 2007).

To help students learn the cultural and domain contexts of problems, context-specific one-to-one scaffolding may be optimal. Computer-based generic scaffolding may be ideal to help students learn about the group dynamics by which scientific knowledge is constructed. A mix of context-specific one-to-one and generic computer-based scaffolding may be optimal to help students learn scientific reasoning strategies.

Critical to helping students develop thinking dispositions (e.g., toward clear and deep thinking) is assessment and feedback (Halpern and Butler, 2011). Generic one-to-one scaffolding provided by the classroom teacher is uniquely positioned to provide assessment and feedback to help students understand and move toward such thinking dispositions (Halpern and Butler, 2011). The classroom teacher can contextualize a student's articulation of ideas and dynamically determine what feedback the student needs to improve his/her thinking (van de Pol et al., 2010). Information about thinking dispositions can be provided by generic, augmenting, one-to-one scaffolding and generic computer-based scaffolding. A meta-analysis indicated that effect sizes were highest when instruction on critical thinking dispositions was delivered in a generic manner in the context of a specific course (Abrami et al., 2008). Critical evaluation of strategies is crucial to the development of critical thinking dispositions (Friedel, 2006; Ku and Ho, 2010), but students may not be able to provide such feedback by themselves in the form of metacognition (Azevedo, 2005).

Basic thinking techniques include decision making, problem solving, remembering, and justification (Perkins, 1995). It makes sense to use generic computer-based scaffolds because such strategies are generic (Schunn and Anderson, 1999), and if any content knowledge needs to be applied along with the strategies, it can be learned through other means. This also would allow students to have access to such support when they need it, rather than simply when the teacher is available.

Tool use involves employing strategies such as brainstorming, concept maps, stepwise strategies, and graphic organizers (Perkins, 1995). Brainstorming and concept mapping has been successfully supported by generic computer-based scaffolding (Cho and Jonassen, 2002; Gijlers et al., 2009). Following a generic approach may be best because these are generic processes that can be used in multiple contexts (Chen et al., 2011; Dougherty et al., 2012). Furthermore, students can be stimulated to uncover relevant concepts for their concept maps, for example, through one-to-one scaffolding related to situation-specific thinking techniques.

Process-specific thinking skills involve utilizing specific thinking systems such as logical, mathematical, scientific, or linguistic systems in appropriate fields. To solve mathematical problems or create scientific explanations, students might need to use process-specific thinking skills such as formal deduction, taxonomies, or probability (Perkins, 1995). These thinking skills can still be applied in many contexts and the general approach does not vary much across fields. Therefore, process specific thinking skills are optimally supported through generic computer-based scaffolding.

Field-specific thinking techniques are specialized forms of thinking dispositions, skills and techniques applied within a particular field (Perkins, 1995). Although certain basic thinking techniques or process-specific thinking skills are generic in nature, the way to utilize them can vary across different fields. For instance, one basic thinking technique - justification - is involved in many fields that call for evidence and arguments. However, what counts as evidence can vary by field and professions. Acquiring and utilizing field-specific thinking techniques is ideally supported through augmenting, one-to-one scaffolding, since augmenting persons can model expert-thinking and behaviors (D. Hung & Chen, 2007). Field-specific thinking techniques may be supported through context-specific computer-based scaffolding and classroom teacher one-to-one scaffolding (McNeill and Krajcik, 2009; Sandoval and Reiser, 2004). One possible way such context-specific support could be embedded into an otherwise generic scaffolding system is to have a space where video can be uploaded of an augmenting person. Alternatively, one could provide augmenting artifacts (cases, living stories, accounts, and ideas that occur in certain fields or professional communities).

Although situation-specific thinking techniques often are special cases of general thinking skills, they have their own distinctive character and consideration for different situations such as experimental design and negotiation. For example, when scientists design experiments, they need to apply and adapt their basic generic thinking techniques such as justification, tool use such as concept maps, process-specific thinking techniques such as deductive logic, and field-specific thinking techniques to solve the problems they have and provide scientific explanations of them. Due to the specificity of situation-specific thinking techniques, these techniques can vary within certain fields or professions. Hence, situation-specific thinking techniques are also ideally supported through augmenting, one-to-one scaffolding (Hung and Chen, 2007), but may also be supported through context-specific computer-based scaffolding (McNeill and Krajcik, 2009) and classroom teacher one-to-one scaffolding. As with field-specific thinking techniques, a possible way such context-specific support could be embedded into an otherwise generic scaffolding system is to have a space where video can be uploaded of an augmenting person or augmenting artifacts could be added.

## 5. SUGGESTIONS FOR FUTURE RESEARCH

A big question is if all scaffolding systems need to incorporate support for each of the six major skills. One consideration is the idea of redundancy in scaffolding such that there is a wide range of supports to fit a wide range of abilities among students (Puntambekar and Kolodner, 2005). According to this paper, multiple forms of scaffolding support diverse skills. More research is needed to see if this model has the potential to support student learning effectively.

It is also unclear how many days augmenting persons would need to come to the unit to afford the emergence of authenticity and support the performance and learning of field-specific and situation-specific thinking techniques. This is potentially the trickiest form of scaffolding to implement, because working professionals do not have unlimited free time to devote to supporting student learning.

Another question relates to the role of peers in helping students develop scientific reasoning skills. The scope of this paper did not allow peer scaffolding to be explored, but peer scaffolding is important to the development of higher-order thinking skills (Hakkarainen, 2004). In problem-based learning, group dynamics are central to student success (Hung, 2011). A natural question is if there is a way to integrate peer scaffolding into the approach outlined above.

## 6. CONCLUSION

As is argued in this paper, it is important for the research community to consider how to balance context-specific and generic, as well as teacher and computer-based scaffolding, to effectively support students higher-order thinking abilities during instruction centered on authentic scientific problem solving. We proposed an heuristic to this end centered on the seven thinking skills coined by Perkins (1995). This involves a big shift in the mode of thinking of scaffolding scholars. It is our hope that this paper provides the initial push to extend the initial ideas of a distributed cognitive system to include generic and context-specific scaffolding in addition to teacher and computer-based scaffolding as well as computer-based and teacher scaffolding (Puntambekar and Kolodner, 2005).

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