Chapter 5

Computer-Based Scaffolding Strategy

Abstract This chapter covers variations in scaffolding strategies along the following characteristics—scaffolding function (e.g., strategic and conceptual), context specificity (i.e., generic or context-specific), customization (e.g., fading and fading/adding), and customization schedule (e.g., self-selected and performance-based). These variations and the theoretical basis for these are explained. Then, results from the meta-analysis are shared, which indicate that there are no differences in cognitive outcomes according to scaffolding function, context specificity, and customization. These results are then discussed.

Keywords Adding · Conceptual scaffolding · Context-specific · Fading · Fading/adding · Fixed customization · Generic · Metacognitive scaffolding · Modeling · Motivation scaffolding · Performance-based customization · Question prompts · Strategic scaffolding · Scaffolding customization · Self-selected customization

5.1 Rationale for Chapter

There is a very large literature on what computer-based scaffolding should do and why, including conceptual frameworks (e.g., Belland, Kim, & Hannafin, 2013; Quintana et al., 2004) and guidelines derived from empirical studies (e.g., Lee & Songer, 2003). While these articles and other reports are often well referenced, by necessity, they only draw on some of the empirical studies/evidence on computer-based scaffolding as well as theoretical analysis. Furthermore, their messages about what forms of scaffolding are most effective are often conflicting. As such, it is difficult for scaffolding designers and researchers to know what scaffolding approaches are most effective under what circumstances.

A key goal of the meta-analysis that I completed with my colleagues was to synthesize empirical evidence on scaffolding so as to uncover the most effective scaffolding strategies in science, technology, engineering, and mathematics (STEM)

education. This way, scaffolding designers and researchers could have solid, empirically based rationales for using one strategy over another in a particular context. And in the case that variation of a scaffolding characteristic did not influence cognitive outcomes, designers could be relatively confident that their choice would not adversely affect student learning one way or the other¹.

To accomplish this, it was first important to think about ways in which scaffolding strategies can vary. The first such way is the scaffolding function, defined as the focus of its support (Hannafin, Land, & Oliver, 1999). This is different from scaffolding's intended outcome in that scaffolding function focuses on the areas in which scaffolding needs to assist students so as to facilitate student success at the target task. Scaffolding function can be categorized into conceptual scaffolding, strategic scaffolding, metacognitive scaffolding, and motivation scaffolding (Belland, Kim, et al., 2013; Hannafin et al., 1999), each of which is described in the sections that follow, along with meta-analysis results on the relative influence of each type of scaffolding on cognitive outcomes.

Next, one can consider scaffolding in terms of whether it contains embedded content knowledge (context-specific) or not (generic) (Belland, Gu, Armbrust, & Cook, 2013; Davis, 2003; McNeill & Krajcik, 2009). This has to do with whether context-specific information is embedded in the scaffolding support. For example, consider a scaffold that helps students consider where to build a power plant. A generic version of the scaffold may provide a generic process by which individuals can (a) identify needed characteristics of a site for an industrial building, (b) identify locations that have at least some of those characteristics, (c) list pros and cons of the different identified sites, and (d) select a site and build a rationale for why the site is appropriate. A context-specific version may be tailored entirely to the choice of a location for a power plant, and all prompts would be couched in that context. Furthermore, a context-specific scaffold may include the options from which students can choose as well as the information with which students will make their decision. Decisions to embed such information are often based on theories of whether target skills are context-specific or generic (Davis, 2003), a question on which there is much disagreement (Perkins & Salomon, 1989). In the following sections, this scaffolding characteristic is explained, along with the influence of each level of this variable on scaffolding's influence on cognitive outcomes.

Finally, one can consider scaffolding in terms of how it is (or is not) customized. Customization can include fading, adding, fading/adding, or none, and can be done on the basis of performance, self-selection, a fixed schedule, or none (Collins, Brown, & Newman, 1989; Koedinger & Corbett, 2006; Pea, 2004).

¹ Note: One needs to consider results of meta-analyses alongside results of other research, especially qualitative and other research that would be excluded from meta-analyses. Also, it is important to note that the current meta-analysis only included cognitive outcomes. Other outcomes such as motivational ones are also important in a holistic assessment of the influence of an instructional approach.

5.2 Scaffolding Function

Scaffolding functions include conceptual scaffolding, strategic scaffolding, meta-cognitive scaffolding, and motivation scaffolding (Belland, Kim, et al., 2013; Hannafin et al., 1999). These are detailed in the following sections, and results from the meta-analysis comparing the effectiveness of such functions are presented.

5.2.1 *Conceptual Scaffolding*

Conceptual scaffolding guides students in terms of things to consider when solving problems (Hannafin et al., 1999; Sandoval & Reiser, 2004). In any problem, there are a multitude of possible things to consider when solving it, and thus it is important to help students narrow these down and choose more productive considerations (Jonassen, 2000) and make sense of the data and information encountered (Ford, 2012; Quintana et al., 2004). Such scaffolding can take a more structured approach when informed by ACT-R (Anderson, Matessa, & Lebiere, 1997) or knowledge integration (Linn, Clark, & Slotta, 2003), or a less structured approach when informed by activity theory (Belland & Drake, 2013; Luria, 1976). In computer-based scaffolding, conceptual scaffolding can take the form of expert modeling in which an expert discusses what aspects of a problem he/she would consider in the process of addressing a problem (D. D. Li & Lim, 2008; Pedersen & Liu, 2002). For example, in *Alien Rescue*, an expert discussed what considerations he would make when considering what planet to choose as a new home for a stranded alien (Pedersen & Liu, 2002). This led experimental students to develop significantly stronger rationales for their problem solutions and to be less likely to ask vague questions than control students (Pedersen & Liu, 2002). Expert modeling would likely be seen more often in scaffolding informed by activity theory than in scaffolding informed by ACT-R or knowledge integration.

Conceptual scaffolds can also invite students to plan animations or experiments, directing them to areas of planning that are particularly important and to which students should pay great attention, and simplifying areas that are not central to learning goals (Reiser, 2004). For example, a scaffold invited students to plan a chemical reaction animation they would create, create the animation in a modeling tool, explain the meaning of the animation and relate it to the phenomenon it describes, and evaluate it (Chang, Quintana, & Krajcik, 2009). Engaging in the full process led students to perform better on a test of chemistry achievement, as well as animation and interpretation quality, as compared to students who either just designed and created the animation, or designed, created, and interpreted the animation (Chang et al., 2009). In another example, students can use a simulation to model the behavior of ions near a cell membrane (Nichols, Hanan, & Ranasinghe, 2013). Students can modify the number of potassium or sodium channels and see how the simulation responds, and they also read prompting questions that indicate important elements

to consider (Nichols et al., 2013). It was found that experimental students engaged in richer collaborative discussions and evidenced less misconceptions on a posttest than control students (Nichols et al., 2013).

Conceptual scaffolds can also use such tools as concept mapping to list important concepts in the material being learned and invite students to make connections between such concepts explicit through the use of connecting arrows (Chin, Dohmen, & Schwartz, 2013). Then, pedagogical agents (teachable agents) are asked questions, and the veracity of their answers depends on the appropriateness of the connections made in the concept map (Chin et al., 2013). This approach led experimental students to perform significantly better on tests of content knowledge and the ability to organize explanations according to categories (e.g., carnivore vs. herbivore) (Chin et al., 2013). In another example, *Belvedere* invited high school students to create claims, evidence elements, and premises, and to make connections among the different elements to create an evidence-based argument (Toth, Suthers, & Lesgold, 2002). Students who were invited to engage in concept mapping and to reflect on their work performed significantly better in overall reasoning than students who engaged in mapping without reflection, as well as students who wrote prose with and without reflection (Toth et al., 2002). In another example, elementary students conducting web-based inquiry were given a concept mapping tool along with guidance on how to link different concepts they encountered/were learning, and also guidance for searching and presentation design (MacGregor & Lou, 2004). Students who used the scaffolding recalled significantly more content from the investigation and also had significantly more creative and organized final presentations (MacGregor & Lou, 2004).

5.2.2 Strategic Scaffolding

Strategic scaffolding bootstraps a strategy that students can use to solve a problem (Hannafin et al., 1999; Reiser et al., 2001). From an activity theory perspective, this approach would still leave open the possibility for student agency in the application of the strategy, and possible modification thereof. This is because according to this framework, the semiotic process of building signs according to tools (e.g., scaffolds) is highlighted (Belland & Drake, 2013; Wertsch & Kazak, 2005). For example, a scaffold bootstrapped positive collaboration skills by providing a database of positive groupwork rules, inviting students to (a) create their own groupwork rules, (b) evaluate their group processes in light of the group rules they created, (c) discuss according to given discussion questions, and (d) self-evaluate the whole process (Ulcsak, 2004). Experimental students engaged in more lengthy discussions and exhibited greater reflection (Ulcsak, 2004). As another example, the *Connection Log* leads middle school students through a generic argument creation process (Belland, 2010) grounded in the persuasive theory of argumentation (Perelman & Olbrechts-Tyteca, 1958). This led lower-achieving experimental students (Belland, Glazewski, & Richardson, 2011) and average-achieving experimental

students (Belland, 2010) to evaluate arguments significantly better than their control counterparts.

From an ACT-R perspective, the possibility for choice in the application of the strategy would be limited due to the desire to minimize unsuccessful practice (Anderson, 1983; Koedinger & Corbett, 2006). For example, in an intelligent tutoring system designed to help students learn LISP programming, the system provides a LISP programming task for students to do and a template for programming elements that need to be in the program (Corbett & Anderson, 2001). Students can type programming commands in a window, and the system checks the code and provides either immediate feedback, error flagging, or self-selected feedback (Corbett & Anderson, 2001). Such feedback was designed so as to promote speed in reaching the correct answers, consistent with the assumption in ACT-R that struggle is not desirable (Anderson et al., 1997). Students who received feedback made significantly fewer errors on the posttest than students who did not receive feedback (Corbett & Anderson, 2001).

From a knowledge integration perspective, choice may be allowed to the extent to which students' existing problem-solving schemas would be elicited and compared to provided normative strategies (Linn et al., 2003). But at the same time, allowing for student choice in the use of strategies is not an overt goal from the knowledge integration perspective in that the existence of normative strategies is posited.

5.2.3 *Metacognitive Scaffolding*

Metacognitive scaffolds invite and help students to evaluate their own thinking (Cuevas, Fiore, & Oser, 2002; Hannafin et al., 1999). Within scientific inquiry, important metacognitive processes include task definition and planning, monitoring and regulating, and reflection (Quintana, Zhang, & Krajcik, 2005). Metacognitive scaffolding can help students with several areas of the metacognitive process, including planning, monitoring and regulating, and reflection (Quintana et al., 2005). Metacognitive scaffolding focused on planning gives students tools for planning and also prompts them to consider the importance of the planning process (Azevedo, 2005; Quintana et al., 2005). Metacognitive scaffolding to enhance monitoring and regulating can focus on monitoring one's progress through the inquiry task according to a set of mileposts (Cuevas et al., 2002; Zhang & Quintana, 2012). Metacognitive scaffolding to enhance reflection can invite students to evaluate the quality of ideas and products generated according to rubrics (Cuevas et al., 2002; Quintana et al., 2005). For example, this may be by giving students criteria to make the evaluation and a forum in which to do so. A metacognitive scaffold invited middle school mathematics students to respond to questions emphasizing comprehension, connection, strategy, and reflection (Kramarski & Hirsch, 2003). Students who used the metacognitive scaffolding performed significantly better on a posttest of algebraic thinking than control students (Kramarski & Hirsch, 2003).

In another example, university students were given prompts encouraging them to stop and reflect on their answers to two questions regarding human immune systems, and a concept map they made with the pertinent concepts (Ifenthaler, 2012). These prompts were either generic or context-specific; students who received the generic prompts gained significantly more from pre- to posttest of domain-specific knowledge than students who received context-specific prompts and those in the control group (Ifenthaler, 2012).

Metacognitive scaffolds are not universally effective. For example, a metacognitive scaffold contained three tools to help college students during a computer literacy test—a project planning sheet, a tool to make connections in information, and a project reflection sheet (Su & Klein, 2010). Students who received metacognitive scaffolds performed significantly worse on a posttest than students who received conceptual scaffolds (Su & Klein, 2010). In another example, backward design strategic scaffolding used in conjunction with reflection rubrics helped high school science students judge the quality with which they collected data and other information, as well as the quality of their research reports and their peer reviews (Deters, 2008). Backward design scaffolding by itself led to a statistically significant and substantial effect on lab report quality, but when reflective prompts were used in conjunction with backward design scaffolding, there was no difference between the performances of experimental and control students (Deters, 2008).

5.2.4 *Motivation Scaffolding*

Motivation scaffolds primarily aim to enhance students' academic motivation toward the target content, defined as their willingness to deploy effort to carry out learning tasks (Tuckman, 2007; Wigfield & Eccles, 2000). This can be done through one of the following processes or a combination thereof: enhancing students' (a) expectancies for success, (b) perceptions of value in the completion of the target task, (c) perceptions of self-determination of behavior, (d) perceptions of mastery goals, (e) abilities to regulate academic emotions, and (f) perceptions of belongingness (Belland, Kim, et al., 2013). Strategies to do so include establishing attainment value, supporting productive attribution, and promoting the perception of optimal challenge (Belland, Kim, et al., 2013). Scaffolds have helped promote expectancy for success through inviting students to reflect on the efficacy of strategies (Davis & Linn, 2000; Herrenkohl & Cornelius, 2013). In addition, providing attributional feedback that guides middle school students to attribute failure to lack of effort and success to good strategy use has been found to lead to stronger motivation and self-concept among experimental students than among control students (Dresel & Haugwitz, 2008). Researchers deploy motivation scaffolds to increase engagement in the target content (Rienties et al., 2012) and to raise academic achievement (Belland, Kim, et al., 2013).

Historically, most designers aimed to create computer-based scaffolding that provided cognitive or motivational support, despite the importance of the integration of these two types of support (Belland, 2014; Belland, Kim, et al., 2013; Rienties et al., 2012). This approach leaves it entirely to one-to-one or peer scaffolding to

provide the form of support that computer-based scaffolding does not. Motivation can make a big difference in students’ performance in academic tasks, including the type of high-level tasks with which scaffolding is used (Belland, Kim, et al., 2013; Bereby-Meyer & Kaplan, 2005; Brophy, 1999; Giesbers, Rienties, Tempelaar, & Gijsselaers, 2013; Perkins & Salomon, 2012). Expecting all cognitive support to be provided by computer-based scaffolds, and all motivational support by one-to-one scaffolding, or vice versa, is not likely the best choice. That is, in a typical classroom, there is one teacher, and that one teacher cannot work with all students at all times (Belland, 2012; Belland, Burdo, & Gu, 2015; Hogan & Pressley, 1997; Saye & Brush, 2002).

An alternative to assigning one scaffolding function to one-to-one scaffolding and another scaffolding function to computer-based scaffolding is to design scaffolding systems to provide redundancy in support such that students receive all needed support even if the teacher needs to work one-to-one with a struggling small group for an extended period of time (Puntambekar & Kolodner, 2005; Tabak, 2004). Such a scaffolding system can include computer-based scaffolding, peer scaffolding, and one-to-one scaffolding, and redundancy can be across and within scaffolding types (Belland, Gu, et al., 2013; Puntambekar & Kolodner, 2005). Providing such redundancy may allow students to be more likely to benefit from scaffolding support at the time they need it than if such support were only provided by one scaffolding mode (Puntambekar & Kolodner, 2005).

5.2.5 Results from the Meta-Analysis

The meta-analysis included 227 outcomes of conceptual scaffolding ($g=0.48$), 28 outcomes of metacognitive scaffolding ($g=0.42$), 75 outcomes of strategic scaffolding ($g=0.44$), and 3 outcomes of motivation scaffolding ($g=0.41$; Note: to be included, outcomes needed to be cognitive) (see Table 5.1; Belland, Walker, Kim, & Lefler, In Press). There were no statistically significant differences among scaffolding types, $p>0.05$. One interesting aspect of this finding is that it suggests that metacognitive scaffolding leads to strong learning outcomes. Metacognitive scaffolding has often been criticized, in part due to observations in the literature that students often do not use it (Belland, Glazewski, & Richardson, 2008; Oliver & Hannafin, 2000). But results suggest that it is as effective as other major scaffolding types. This provides a preliminary suggestion that rather than attempt to choose

Table 5.1 Table of results of moderator analyses on the effect of type of scaffolding intervention on cognitive outcomes

Level	<i>n</i> outcomes	Effect size estimate	95 % Confidence interval	
			Lower limit	Upper limit
Conceptual scaffolds	227	0.48	0.41	0.54
Metacognitive scaffolds	28	0.42	0.23	0.60
Motivation scaffolds	3	0.41	−0.02	0.85
Strategic scaffolds	75	0.44	0.36	0.53

a scaffolding type that is most effective and design accordingly, it is better to first decide on the nature of support students need, and then design the scaffolding support accordingly.

5.3 Context Specificity

In this section, I first describe what context specificity is with regard to scaffolding. Then, I address what the meta-analysis indicates about differences in effect sizes between context-specific and generic scaffolding.

5.3.1 What It Is

There has been much debate as to whether it is important to embed context-specific support in computer-based scaffolds. Much of this has to do with long-standing debates as to whether problem-solving skills are generic or context-specific; for an overview of the latter debate, see Perkins and Salomon (1989) and Schunn and Anderson (1999). Within one-to-one, teacher scaffolding, this question would be of little importance, as teachers can dynamically determine if such contextual support was needed. But given that computer-based scaffolding is designed before students use it, it is an important question to consider (Akhras & Self, 2002; Belland, 2014).

Computer-based scaffolding can be tailored to specific content or designed to be more generic in its approach (Belland, 2014; McNeill & Krajcik, 2009). For example, *ExplanationConstructor* was designed to be context specific (Sandoval & Reiser, 2004). Thus, all of its prompts included specific content related to the problem that students were addressing—microevolution among ground finches in the Galapagos Islands. As an example of a generic scaffold, the *Collaborative Concept Mapping Tool* was designed to facilitate groups' shared creation of concept maps in conjunction with units of different topics (Gijlers, Saab, Van Joolingen, de Jong, & Van Hout-Wolters, 2009).

One of the arguments advanced for using context-specific scaffolding is the idea that problem-solving skills are usually context bound, which emerged in part as a reaction against the practice of developing problem-solving heuristics based on such games as Towers of Hanoi and Missionaries and Cannibals (Perkins & Salomon, 1989). However, there is a strong evidence that problem-solving involves a mix of domain-specific and generic skills (Klahr & Simon, 1999; Molnár, Greiff, & Csapó, 2013; Perkins & Salomon, 1989; Schunn & Anderson, 1999). In this way, it is important to consider the nature of the subskill that one wishes to support through scaffolding in order to decide whether to use context-specific or generic scaffolding (Belland, Gu, et al., 2013).

There is not a large amount of research that directly compares the effectiveness of generic and context-specific scaffolds. A pilot meta-analysis found no difference in effect sizes between context-specific and generic scaffolds (Belland, Walker, Olsen,

Table 5.2 Results of moderator analyses on the effect of type of context specificity on cognitive outcomes

Level	<i>n</i> outcomes	Effect size estimate	95% Confidence interval	
			Lower limit	Upper limit
Context-specific	273	0.46	0.41	0.52
Generic	60	0.48	0.35	0.60

& Leary, 2015). However, there is some evidence about specific questions related to context-specific and generic scaffolding. For example, there is some evidence that generic prompts for reflection promote better science learning among middle school students than context-specific ones (Davis, 2003). However, reflection is not the only process supported by scaffolding. There is also evidence that synergy is promoted when teachers provide one-to-one scaffolding from the perspective of a generic argumentation framework and computer-based scaffolds provide context-specific argumentation scaffolding, thereby maximizing middle school students’ learning of argumentation (McNeill & Krajcik, 2009).

Rather than simply declaring that generic or context-specific scaffolding is the best, a better approach may be to consider how to combine context-specific and generic scaffolding, as well as one-to-one and computer-based scaffolding, according to the types of skills to be supported and the inherent strengths of a generic approach versus that of a context-specific approach, and that of a one-to-one versus a computer-based approach (Belland, Gu, et al., 2013). That is, one can consider how to create a portfolio of generic and context-specific scaffolding that optimally supports student learning and performance.

Beyond the suitability of scaffolding strategies for supporting specific skills, there are considerations regarding scalability. If a scaffold is entirely context-specific, then all of its instructional messages are inextricably tied to the specific content with which students are working in the target unit (Belland, Gu, et al., 2013). As such, the scaffold can only be used in the context of the target unit. Generic scaffolds use language that is not tied to the target unit such that they can be used in conjunction with other units.

5.3.2 Results from Meta-Analysis

The meta-analysis included approximately 4.5 times as many outcomes from studies that investigated context-specific scaffolds (*n*=273) than from studies that investigated generic scaffolds (*n*=60) (see Table 5.2; Belland, Walker, Kim, & Lefler, In Press). When one considers that 82 % of included outcomes in the meta-analysis were associated with context-specific scaffolding, it seems clear that scaffolding designers are choosing to design context-specific scaffolding more often than generic scaffolding. This may be based on the idea that the type of strategies that one tried to promote through scaffolding (e.g., problem-solving strategies) are inherently context-specific and cannot be performed or learned sufficiently without

an adequate base of conceptual knowledge. But there was no significant difference between the average effect sizes when generic scaffolding ($g=0.48$) and context-specific scaffolding ($g=0.46$) were used, $p=0.778$. This suggests that arguments that problem-solving and other strategies are context-specific and need to be supported by context-specific scaffolding are not supported by the corpus of empirical evidence on computer-based scaffolding in STEM education, or at least that which met the inclusion criteria (namely, met scaffolding definition, had an experimental and a control group, and contained sufficient information to calculate an effect size). That is, students seem to do equally well whether domain knowledge is embedded in the scaffolding or not. Thus, scaffolding designers can choose to use generic or context-specific scaffolding based on a determination of which strategy works best under the constraints of the learning context, rather than a consideration of which strategy is the most effective (Belland, Gu, et al., 2013).

5.4 Customization Presence or Absence

One of the biggest sticking points as the metaphor of scaffolding was applied to computer-based tools was the issue of contingency—namely, whether scaffolding was added, faded, or added and faded based on an estimation of the current ability of the student. As computer-based scaffolding was introduced, much lacked anything in the way of contingency, leading some authors to question whether the tools could be called scaffolding at all (Pea, 2004; Puntambekar & Hübscher, 2005). Indeed, Pea (2004) noted that such tools may be better described as part of distributed cognition, defined as a system in which information and an executive function are distributed among various individuals and tools such that no one entity carries out the entire extent of cognition required by the task (Belland, 2011; Giere, 2006). Most such arguments have been voiced by researchers from the activity-theory- and knowledge-in-integration-informed scaffolding traditions. This is perhaps because fading and adding is consistently applied in ACT-R-informed scaffolding (Koedinger & Aleven, 2007).

A closer look at the nature of scaffold fading, adding, and fading/adding is warranted. Fading refers to gradually removing support as students gain skill (Collins et al., 1989; Wood, Bruner, & Ross, 1976). One can base fading on dynamic assessment of students' capabilities, though fading in much computer-based scaffolding is based on self-selection and fixed intervals. Fading can involve but is not limited to gradually transitioning students to a less supportive/directive form of support, lessening the frequency of prompts, and lessening the specificity of feedback. For example, one scaffold for high school students progressed from providing sentence starters in the body of a text box to a simple prompt to formulate sources to no prompt at all; this progression happened on a fixed schedule (Raes, Schellens, De Wever, & Vanderhoven, 2012).

Adding support refers to increasing the strength or frequency of support as performance indicators show that students need more support (Koedinger & Aleven, 2007). As with fading, this should be implemented on the basis of dynamic assessment, though it is often based on self-selection (Koedinger & Aleven, 2007).

Table 5.3 Results of moderator analyses on the effect of customization on cognitive outcomes

Level	<i>n</i> outcomes	Effect size estimate	95% Confidence interval	
			Lower limit	Upper limit
Fading	12	0.62	0.38	0.87
Adding	62	0.46	0.35	0.56
Fading/adding	43	0.50	0.36	0.63
None	216	0.46	0.39	0.52

Adding can involve providing more directive support, providing additional feedback of a different nature, and increasing the frequency of prompts. For example, the *Mobile Knowledge Constructor* invited students to find a plant in a garden (Chu, Hwang, & Tsai, 2010). It then asked questions about features of the target plant. If students answered incorrectly, it guided them to another plant that has the mistaken feature. After studying the new plant, students needed to answer the question they missed again.

Fading and adding is simply the combination of fading and adding within the same scaffolding treatment. As with fading and adding, fading/adding should be performed on the basis of dynamic assessment. Accordingly, fading occurs when performance indicates that students are gaining sufficient skill to perform the target task independently, whereas adding occurs when students are not on track to improve as rapidly as desired. For example, a scaffolding system broke content to be learned into different blocks (S. Li, 2001). For each block, there were four levels of support possible: no support, provide hint, provide example, and provide answer. Students started out at the hint level. In the system-controlled version, if they answered correctly, they would be moved down to no support. If they answered incorrectly, then they would be provided an example, and so on.

No fading/adding means that there is no customization of scaffolding. In other words, scaffolding is the same throughout students’ engagement with the central problem. Researchers often argue that not-fading/adding can lead to overscripting, a situation in which scaffolding is provided when it is in fact not needed, thereby conflicting with existing mental models of how to address the targeted problem (Dillenbourg, 2002). This in turn is said to lead to weaker learning outcomes.

5.4.1 Results from Meta-Analysis

It makes sense to take a step back from the theoretical arguments to see if scaffold customization actually impacts cognitive outcomes. The scaffolding meta-analysis covered outcomes of scaffolds that incorporated several variations of contingency—fading (*n*=12), adding (*n*=62), fading and adding (*n*=43), as well as no fading or adding (*n*=216) (see Table 5.3) (Belland et al., In Press). Thus, the majority of outcomes were associated with no fading or adding (64.9%). Of the included outcomes, 16.5% were associated with scaffolding that incorporated

fading in some way, either just fading, or fading and adding. This is close to what was found in the review of scaffolding research by Lin et al. (2012), who found that 9.3% of the reviewed studies incorporated fading. And it is generally consistent with the lamentations of scaffolding scholars (Pea, 2004; Puntambekar & Hübscher, 2005). This appears to confirm that fading is rarely incorporated in scaffolding.

There was no significant difference in cognitive outcomes among the different contingency types. This is interesting in that authors often lament the lack of attention to scaffolding customization. But the results indicate that the presence or the type of scaffolding customization does not influence cognitive outcomes. Simply put, from a cognitive outcome standpoint, incorporating fading, adding, or fading/adding made no difference. This suggests that researchers might be best served considering other scaffolding factors in their quest to maximize student learning from scaffolding.

5.5 Customization Basis

While in the original scaffolding definition, customization was based on a teacher's assessment of students' performance indicators (Wood et al., 1976), customization of computer-based scaffolding has not always been performance based. When scaffolding is customized based on performance indicators, the scaffolding engages in dynamic assessment of student performance. For example, students may need to complete a quiz. Based on their score, scaffolding is customized. This is often done in intelligent tutoring systems (Koedinger & Corbett, 2006).

Other strategies used as the basis of the customization of computer-based scaffolding included setting scaffolding to reduce in strength according to fixed time intervals (fixed fading) (Dori & Sasson, 2008; McNeill, Lizotte, Krajcik, & Marx, 2006; Philpot, Hall, Hubing, & Flori, 2005) or when students click a button (self-selected fading) (Clark, Touchman, Martinez-Garza, Ramirez-Marin, & Skjerping Drews, 2012; Metcalf, 1999; Renkl, 2002). Customization based on fixed time intervals means that the scaffold designer determines time intervals after which scaffolding should be faded or added. Once the time interval is passed, the scaffolding would be added or faded automatically. Self-selection means that a button is provided with which students can request hints (adding) or request that scaffolding be removed (fading). For example, adding scaffolding (hints) has also been linked to pressing buttons in intelligent tutoring systems (Koedinger & Aleven, 2007), and fading has been controlled by students who press a button indicating that they perceive that they do not need the scaffolding any longer (Metcalf, 1999). The rationale for the use of self-selection in adding in intelligent tutoring systems is to avoid unproductive struggle, and it is thought that students can recognize that they are struggling too much (Koedinger & Aleven, 2007). Similarly, in self-selected fading, it is thought that learners can accurately gauge the extent to which they need scaffolding assistance at a given point in a learning task (Metcalf, 1999). This relies on learners to make good instructional decisions, which they often struggle to do (Williams, 1996). Furthermore, fixed and self-selected customization does not appear to fit the

original definition and may not have been performed on the basis of performance characteristics (Belland, 2011).

Sometimes, scaffolding can be customized on the basis of performance indicators and self-selection. For example, students may self-select a level of scaffolding that they want before engaging with the scaffold; as they engage in the system, the system may provide feedback and suggestions to adjust the self-selected scaffolding level on the basis of performance characteristics (Cheng et al., 2009). Intelligent tutoring systems often provide feedback on the basis of performance indicators, but students can also request more help by clicking a hint button. If the first hint does not help enough, the student can click the hint button again to get a more detailed hint, until eventually he/she is given the solution (Koedinger & Aleven, 2007). Intelligent tutoring systems based on the ACT-R model of cognition guide students through a task using several strategies, including providing choices on what methods to use to solve the target problem, feedback on what students do, and hints on how to accomplish certain steps (Koedinger & Aleven, 2007; Koedinger & Corbett, 2006; VanLehn, 2011). According to ACT-R, complex cognitive domains can be seen as a set of production rules and declarative knowledge, and such production rules can be learned independently (Anderson, 1983; Anderson et al., 1997; Koedinger & Aleven, 2007). Hints are designed to reduce the amount of unproductive practice in which students engage, which ACT-R posits as an impediment to learning (Anderson, 1990; Anderson et al., 1997). Sometimes, hints are requested by students, and sometimes they are provided based on the intelligent tutoring system's estimation of student ability. Intelligent tutoring systems also keep track of students' abilities through knowledge tracing (Koedinger & Aleven, 2007; Koedinger & Corbett, 2006). In this way, they estimate whether students know or do not know the production rule under study. Through knowledge tracing, an intelligent tutoring system can estimate when a student is ready to proceed to the next unit and select problems of appropriate difficulty (Koedinger & Aleven, 2007; Koedinger & Corbett, 2006). It can also determine when a student needs more or less support, and adjust the support accordingly.

Preliminary meta-analyses of scaffolding indicated that fixed fading led to an average effect that was not significantly different from zero (Belland, Walker, Kim, & Lefler, 2014; Belland, Walker, et al., 2015). Linking customization to self-selection poses challenges as well. In the case of intelligent tutoring systems, hints usually become successively more detailed/supporting, causing some students to game the system by pressing the button multiple times until they get the answer (Koedinger & Aleven, 2007). Furthermore, computer-based scaffolding rarely incorporates feedback (Belland, 2014).

5.5.1 Results from Meta-Analysis

Again, taking a step back from the theoretical arguments, it is important to examine whether the basis by which scaffolding is faded, added, or faded and added influences cognitive outcomes. Of the outcomes in which scaffolding customization was

Table 5.4 Results of moderator analyses on the effect of customization schedule on cognitive outcomes

Level	<i>n</i> outcomes	Effect size estimate	95 % Confidence interval	
			Lower limit	Upper limit
Performance-based	63	0.47	0.35	0.60
Fixed	13	0.62	0.42	0.82
Self-selected	41	0.45	0.35	0.55
None	216	0.45	0.39	0.52

present, 53.8% involved performance-based customization, 35 % involved self-selection, and 11.1 % involved fixed customization (See Table 5.4; Belland et al., [In Press](#)). Of note, many scaffolding interventions that incorporated performance-based customization were embedded in intelligent tutoring systems. In such cases, even though there was often both performance-based fading and self-selected adding, the scaffold was classified as performance-based since the performance-based customization would always be present and theoretically always happen, while self-selected adding would only happen if students clicked the hint button. Future research may attempt to disentangle such combinations of scaffolding bases to tease apart the effect of these different scaffolding components. However, this would be difficult as one would likely need to be able to attribute outcomes to specific scaffolding components for which customization was performance-based, and other outcomes to other outcomes that were self-selected. The inclusion of such outcomes that can be easily attributed to separate scaffolds is quite rare.

There were no statistically significant differences among the scaffolding customization bases. This means that there were no differences between performance-based customization, fixed customization, self-selected customization, and no customization. This largely flies in the face of the generally accepted consensus among scaffolding scholars that scaffolding customization is better than no scaffolding customization, and that performance-based customization is the best of all. From a statistical standpoint, there was no difference in cognitive outcomes. This is very interesting. Of course, further research is needed to understand the role of scaffolding customization and scaffolding customization bases in STEM learning. For example, only cognitive outcomes were included; there may be differences in terms of motivation or self-direction. This finding conflicts with the findings from a pilot scaffolding meta-analysis that indicated that when scaffolding was not faded, effect sizes were higher than when scaffolding was faded on a fixed schedule (Belland, Walker, et al., [2015](#)). In yet another prior scaffolding meta-analysis, fixed fading led to an effect size that was not significantly greater than zero, while not-fading led to an effect size that was significantly greater than zero (Belland et al., [2014](#)).

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