ABSTRACT

Scaffolding, supports provided to learners allowing them to accomplish tasks they could not do alone, is an important concept in the design of software learning tools and for teaching. The effectiveness of scaffolds designed into a dynamic modeling software tool (Model-It) is assessed over time in three middle school science classrooms. Answers are sought to the following questions: Which scaffolds in Model-It are used effectively by learners? Are scaffolds provided by teachers and/or peers instrumental in supporting the use of Model-It? Does scaffold use change over time? Learner use of the modeling software occurred for nine total hours, spread over a four month time frame in three separate activities. Six learner pairs were videotaped as they used the software. Detailed analysis of the videotapes provided evidence for the changing patterns of scaffold use, the value of some, but not all, scaffolds, and the vital nature of scaffolding provided by teachers and peers.

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1.0 INTRODUCTION

A recent increase in emphasis on national science standards and authentic science inquiries (AAAS, 1998) (NRC, 1996), combined with what can only be described as a boom in educational technology expenditures by schools, have lead to many innovative attempts to place advanced computational technologies in the hands of science learners, in the hopes of improving science learning and engagement. Over the past five years, numerous researchers have constructed educational software tools to explicitly address issues in learning and teaching science. These researchers have demonstrated enhanced educational outcomes, on a limited scale, when using that software with 6th to 12th grade learners (Stratford, 1996; Jackson, 1999; Reiser, 1999; Songer & Samson, 1998; Linn, 1998). However, the design of these tools, and their integration into classroom contexts is far from standardized.

1.1 Background

The software tools in the research listed above attempt to model the practice of real scientists, and support or scaffold the learner as they develop increased competence in scientific methods and increased content or domain knowledge. One particular software tool, known as Model-It, is designed to assist learners in creating dynamic models of scientific phenomena (Jackson et. al, 1999). Of primary concern in the design of this software was the need to scaffold student learning, meaning to provide support (in a variety of forms) for the cognitively complex task of making a model, and the task of using the software. An examination of what scaffolds in the Model-It software and the classroom environment support the development of modeling skills, could yield important benefits for both the specific use of this tool, and the understanding of scaffolding use in educational software in general.

1.2 Scaffolding Defined

A scaffold, or scaffolding, is operationalized, for the purposes of this study, as intentional support provided to a learner from a more knowledgeable other (which could be a technology tool), for pedagogical ends, that either fades (or can fade) after some period of time. Scaffolding is expressly provided to allow the learner to accomplish tasks they could not do alone. This definition attempts to accommodate current conceptions of support, coaching, and modeling, and places scaffolding as a "meta" term (which is not always the case in the literature). Scaffolding can be provided by tools, teachers, or peers, and interactions between the three in pedagogical contexts. The source of the scaffolding has a substantially greater expertise. A tool, in this definition, can have scaffolding, but the tool itself is not thought of as scaffolding. Lastly, "fading", the ability of the scaffolding to change in response to learner development, is considered a requirement to differentiate between a scaffold and more permanent tool interface elements. Recognizing the limits of software programming, we require only that the tool element could fade, not that it actually fade in the current iteration of the program.

2.0 REVIEW OF THE LITERATURE

2.1 Introduction

Scaffolding is a difficult term to track through the literature. It is certainly popular, but not particularly well defined. A solid one-sentence description is support provided for learners to engage in activities that would otherwise be out of reach (Jackson, 1999). As Palinscar (1999) notes, the term scaffolding tends to be "most used yet least understood" because it is a metaphor with great descriptive power. Scaffolding is studied as an aspect of tools (generally software), as teacher interaction with learners, and as learner interaction with peers, but rarely in combination.

Powerful terms are a useful starting point in studying complex learning environments, but naming scaffolding is not the same as explaining it (Schoenfeld, 1999). As of yet we lack an explanatory framework that captures the varied types of scaffolding and the contexts in which it is studied. One such context is in teaching students to use models in science classes.

2.2 Modeling and Science Inquiry

Modeling of complex systems and phenomena is of value in science learning and increasingly emphasized (AAAS 1998; NRC, 1996). Modeling is authentic, it is something scientists do, and in addition, learners engaged in modeling can be engaged in desired pedagogical activities such as: planning, analyzing, critiquing. Designing realistic models is a difficult task, and designing them in a computer environment where they can be dynamic is still more difficult. Learners need support in mastering both software function and the modeling process. Dynamic modeling software (as well as other science focused tools) have been shown to contribute to science learning (Stratford, 1996; Jackson, 1999). These other tools have been designed to support aspects of science learning, such as collaboration, argumentation, and research (Reiser, 1999; Songer & Samson, 1998; Linn, 1998). All of these tools contain at least some support for the tool user, but not all have a formal design theory behind them.

2.3 User Centered Design / Learner Centered Design

One theory of software tool design is Learner Centered Design (LCD), which posits that a learner has unique needs beyond that of a work or operator paradigm (Soloway et al, 1994). This idea is an extension of User Centered Design (UCD), advanced by Norman (1986), which focuses on the analysis of tool interfaces to make the accomplishment of established work practices more effective or efficient. The Human Computer Interaction (HCI) community takes this approach to interface design, with the central assumption that the learner, while different

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from the 'user' in terms of motivation, expertise, and heterogeneity, is still essentially a 'black box' and increased performance on the desired task is evidence of success.

Jackson (1999) developed the concept of Guided Learner Adaptable Scaffolding (GLAS) to formalize how scaffolding might best be applied to the design of software tools, specifically Model-It. In studies of the use of this tool in classrooms (Stratford, 1996), there is little discussion of teacher or peer scaffolding, although this tool was used to support instruction in larger science concepts. In a further development of the scaffolding concept, entire processes are supported by integrated tool suites. The Scaffolded Integrated Tool Environments (SITES) of Quintana (1999), take the 'next step' in supporting mastery of the "wickedly complex" science inquiry process. While not all invoking the UCD or LCD framework, most of the tools mentioned previously have scaffolding as an important aspect of their design (Quintana, 2000; Guzdial et. al, 1998; Bell&Davis, 2000), and share a common focus on learner behaviors.

2.4 Scaffolding from teachers and peers

Although software designers focus on the aspects of scaffolding in tools and their software interface, teacher and peer scaffolding are sometimes studied alone and sometimes studied in conjunction with tools, in a variety of contexts. To study scaffolding from teachers and peers requires a focus on behaviors, whether in reading, disabilities, scientific argumentation, or other contexts. The theoretical framework for thinking about these behaviors is provided by Vygotsky's (1978) ideas of the Zone of Proximal Development (ZPD) and the more specific elaboration of scaffolding as a set of learning strategies by Wood and colleagues (1976).

Vygotsky's ZPD is that area of performance beyond what a learner can accomplish unassisted, where the assistance of a more knowledgeable or capable other allows them to

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complete tasks. The high end of the ZPD, while hard to define, is where the learner cannot make progress (toward mastering the task) even with assistance. A three year old can, over a short period of time with adult guidance, master the process of cleaning up his toys. The same three year old cannot manage the crisis drills at the local power plant, no matter how many times or how much his mother, a plant engineer, assists him. Recognizing the long-standing ubiquity of scaffolding in human learning, Wood et. al (1976) note the "scaffolding functions" of tutoring: motivating, constraining the task, decomposing complex processes, making implicit (expert) understandings explicit.

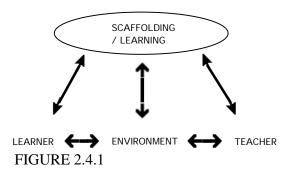
Some studies examine teacher behavior explicitly, such as Palinscar's (1984) Reciprocal Teaching study, where teachers provide scaffolding with their behaviors and a few simple tools such as checklists. In research on scaffolding scientific competence, Hogan (1997) also focuses on teacher behaviors such as tailored assistance, feedback, and assisting reflection. In a further discussion of cognitive apprenticeships, Collins and colleagues (1989) defined scaffolding as a sub-component of coaching, but also identifed scaffolding as "reminders and help", as well as later allowing that scaffolding can also take the form of "physical aids".

Other research has examined teacher behaviors in conjunction with tools, such as Classroom Centered Design (Resier, 1999) which attempts to account for context and specifically the teacher's role in working with a scaffolded software tool. In an explicit attempt to study scaffolding for teachers using tools like Model-It in the classroom, Schrader (1999) developed curricular supports to address common student misconceptions about the modeling process. So, a researcher developed scaffolds, to support a teacher who is scaffolding learners using a software tool, with scaffolding built into it. This captures well the wide variety of areas in which scaffolding is studied.

2.5 Limitations

There are a number of limitations in current research on scaffolding. First and foremost, there are no clear definitions of what scaffolding (or "a scaffold") is. Questions that need to be answered include: What are the sources of scaffolding? Can scaffolding provided by tools be studied without regard to the assistance provided by teachers and peers? At what level of granularity is scaffolding to be considered – can a curriculum be a scaffold? What is the relation of scaffolding to related terms such as modeling, coaching, and supports?

The studies scaffolding in general do not try to account for scaffolding across a continuum, (see figure 2.4.1 below). To succeed in supporting a learner, scaffolding that is not



provided by the tool must come from the teacher or some other aspect of the environment (such as peers). No studies so far have attempted to assess scaffolding from all three sources in the same context. A limitation of most studies is that they assess scaffolding indirectly. The assumption is that if a scaffold is built into a tool (embedded in some larger treatment) in order to support an increase in ability "X", then any subsequent improvement in "X" is taken as evidence of the success of the scaffold. Scaffolds are rarely addressed in and of themselves, and work has only recently begun in developing criteria for assessing scaffold use (Quintan et al., 2000). 2.6 Research Questions / Purpose

We investigate the question "Which scaffolds in Model-It are used effectively and/or work well together?" in association with the following subquestions:

"Do scaffolds outside of Model-It, such as those provided by peers and teachers, seem vital to the use of Model-It and the development of modeling skills?"

"Do we observe changes in use of Model-It scaffolds over time?"

The purpose of this study is to advance the understanding of how tool, teacher, and peer scaffolding interact in classroom contexts, and to inform the design of tool scaffolds in terms of effectiveness and fading.

3.0 METHODS

3.1 Introduction

Methods used to assess scaffolding have varied widely. Scaffolding has been defined in varying levels of detail, and the definition of what counts as successful scaffolding has similarly varied. Scaffolding is one of those powerful terms in educational research that needs to be examined in detail, but still studied in context (Schoenfeld, 1999). Given that most of the studies have examined complex classroom environments, many have used design experiments (Brown, 1992) in conjunction with a wide variety of qualitative and quantitative methods. This variety, while it makes comparing studies difficult, is also beneficial in that it provides multiple perspectives from which to increase our understanding of how scaffolding assists learners in context.

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3.2 Methods used to examine scaffolding

Just as definitions of scaffolding vary, so to do the methods used to assess scaffolding in classroom research. Not all of these studies use the term scaffolding specifically, but all concern themselves with providing supports (in ways that meet the aforementioned definition of scaffolding) to learners. In general, studies focus on classrooms or smaller groups of students, have overall small sample sizes, use audio/video recording to capture behaviors for later analysis, and collect artifacts of student work. Studies used both quantitative and qualitative methods, sometimes in combination (e.g. Salomon, 1990), and most commonly in the format of a design experiment (Brown, 1989).

Quantitative methods are often employed as complimentary to qualitative, generally due to the lack of explicitly experimental designs. Where pre and post tests were possible using standardized tests (Palinscar, 1984; Scardamalia, 1984) they were compared for statistical significance. In other cases, qualitative data, such as behavioral counts or graded artifacts from different times or groups, were analyzed using ANOVAs (Bell&Davis, 2000)

Qualitative methods were employed most often, as the classroom context provide a rich source of descriptive materials. Where behaviors were the focus, classroom observation records and transcripts were used (Palniscar, 1989), and the focus was on how questions were asked (Pressley, 1995) and what types of verbal feedback are provided (Hogan, 1997). Where tools were the added, or sole, focus, then other methods were popular, such as: use of videotapes (Quintana, 1999), coding schemes (Stratford, 1998), event logs from within software (Guzdial et al, 1998), databases of behaviors (Jackson, 1999), and artifact analysis (Jackson, 1999; Stratford, 1988). Many of these studies inform the choice of methods, standards, and techniques chosen for the current study.

3.3 Methods used in this study

This study uses a new combination of established and emerging techniques to make a more detailed examination of how scaffolding is used in classroom contexts. In order to capture both how the learners are using the tool and what they are saying, two process video stations (Krajcik, 1988) record the screen video and learner discussion of two learner pairs. The rest of the class also works in pairs, on computers without the process video equipment. Learners use Model-It dynamic modeling software for three days to make models of some aspect of water quality (the curriculum unit they are working on at the time). Learners have been exposed to related content for several weeks prior to software use, including trips to examine local streams and conducting water quality tests. The process video tapes are transcribed, coded, and the analyzed using NUD*IST software to gather a variety of evidence and develop findings.

3.4 Population

The subjects of this study were from three classrooms of 7th grade science learners (n=43) of an independent 6-12 school in a mid-sized midwestern University city. The learners are mostly white, mid-SES and above. The three experienced teachers each had approximately 18 learners and 8 computers per class. The teachers have embedded use of the Model-It in a previously established science curriculum dealing with water quality and decomposition.

Initial exposure to the software occurs for three 45-minute periods over three days, in a water quality curriculum. This first exposure is one of several during the school year, in this study, we will examine the first three days of Model-It use in detail.

3.5 Analysis

Analysis of the data was an iterative process, with a preliminary review of a subset of tapes allowing a review and revision of the coding scheme and the development of transcribing guidelines. The cycle was repeated several times until a satisfactory degree of agreement was

reached that the coding scheme addressed all the themes and categories seen in the data, and until each coder produced transcripts of the same tape that captured a similar level of detail. Tapes were then divided among coders, transcribed, imported into NUD*IST software, and coded, as described below.

3.5.1 - Transcription

Each tape was transcribed with a standard header and according to agreed conventions, as detailed in appendix C. Standards for denoting changes in tool mode, when to break text into episodes with time marks, what to transcribe verbatim /what to summarize were developed. In general, each half hour of tape yielded three to five pages of text. By iteratively reviewing tapes together, coders developed the ability to create transcripts of essentially equal length, level of detail, and focus. Each coder then transcribed 1/3 of the tapes, imported the transcripts into the NUD*IST software database and coded the transcript in accordance with the coding scheme.

3.5.2 – Coding Scheme

A coding scheme was developed over a three-month period. This coding scheme was structured to address research questions on scaffolding, modeling strategy use, and graph interpretation. The coding scheme was based partly on prior research (Stratford, 1998; Jackson 1999) and then developed as the coders worked through an initial analysis of a subset of the tapes. Second, they coded these transcripts using a coding scheme (Appendix A, and sampled in Figure 3.5.2), and then met to compare their codes, with group discussion of the original video where needed. This process of refining codes iteratively is a well established method (Chi, 1997; Miles&Huberman, 1994), and ensures that the data are fully explored. An example of the iterative process would be code 3.2.5 "Peer Scaffolding-Strategy", where an initial set of four codes was expanded to capture a fifth category of scaffolding that was noticed by coders in the second round of refining.

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1. Administrative	2. Activity	3. Scaffold	4. Modeling Strategy
1.1 School	2.1 Plan	3.1 Tool	4.1 Planning
1.1.1 Greenhills	2.1.1 Create obj	3.1.1 Sequencing tasks: buttons	4.1.1 Generating ideas
1.2 Teacher	2.1.2 Modify Obj	3.1.2 Factoring functionality:	4.1.2 Stating goals
1.2.1 name #1, etc	2.1.3 Del obj	views	4.1.3 Identifying fac/obj or charactr.
1.3 Unit Exposure	2.1.4 Create fac	3.1.3 Hiding Complexity	4.1.4 Specifying relationships
1.3.1 Water Q	2.1.5 Modify fac	3.1.4 Facilitating Articulation:	4.1.5 Discussing factors/objects
1.3.1.1 WQ1	2.1.6 Del fac	Because, description	4.2 Searching
1.3.1.2 WQ2	2.2 Build	3.1.5 Making context personally	4.2.1 Seeking information
1.3.1.3 WQ 3	2.2.1 Create fac	relevant: personalize	4.2.2 Gathering resources
etc	2.2.2 Modify fac	3.1.6 Linking Multiple	4.3 Synthesizing
1.4 Period	2.2.3 Del fac	Representations	4.3.1 Discussing relationships
1.4.1 A	2.2.4 Create rel	3.1.7 Manipulating	4.3.2 Making connections
1.4.2 B	2.2.5 Modify rel	Representations	4.3.3 Deciding how model should work
etc	2.2.6 Del rel	3.2 Teacher	4.4 Analyzing
1.5 Learners	2.3 Test	3.2.1 Conceptual	4.4.1 Deciding about course of action
1.5.1 Name #1, etc	2.3.1 Open meter	3.2.2 Utility	4.4.2 Recognizing the need of test
1.6 Session within Unit	2.3.2 Assign factors to graph	3.2.3 Task	4.5 Explaining
Exposure	2.3.3 Change meter value	3.2.4 Content	4.5.1 Explaining why/how
1.6.1 1 st	2.3.4 Del meter	3.2.5 Strategy	4.5.2 Justifying arguments
etc	2.4 Other	3.3 Peer	4.5.3 Elaborating ideas
1.7 Year/Grade	2.4.1 Shifting	3.3.1 Conceptual	4.6 Evaluating
1.7.1 School year	2.4.2 Off task	3.3.2 Utility	4.6.1 Predicting what should happen
1.7.1.1 99-00 etc		3.3.3 Task	4.6.2 Identifying anomalies
1.7.2 Grade		3.3.4 Content	4.6.3 Critiquing/interpreting the results
1.7.2.1 7 th grade		3.3.5 Strategy	4.6.4 Identifying/proposing solutions
1.7.2.2 8 th grade			4.6.5 Carrying out solutions
-			4.7 Other

Figure 3.5.2 Sample of coding scheme.

Some codes were assigned for tool use and considered mandatory. This means that every time learners used a particular function of the program, such as manipulating a test meter (code 2 2 3), then this same text segment was coded for the manipulating representation scaffold (code 3 1 7). This sort of "cross-coding" can be traced in the coding scheme by matching the colors (see figure 3.5.2). Other scaffolds, however, would be nonsensical to count every time the function was used (e.g. the default setting for relationships, on every use, was qualitative), so unless this setting was explicitly discussed or changed to quantitative, the relevant scaffold code was not assigned. The codes also contained administrative/demographic data(column 1, above), mode and details of tool use(2), teacher/peer scaffolding(3), strategy use(4), and more. Explicit definitions of "what counts" for any code can be found in appendix B. Both peer and teacher scaffolding were based on conversations, generally transcribed verbatim. The reason for such comprehensive coding is that if the codes are not entered for each transcript up front (such as class period, or curriculum unit), then one cannot "slice" the data using these criteria later.

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3.5.3 - Coding and NUD*IST

Once every tape had been transcribed to a text document, the documents were imported into a qualitative analysis program called NUD*IST, one of the more robust qualitative analysis tools (Miles&Huberman, 1994; Erlandson et al, 1993). This software allowed each line of the transcript to be coded with any or all codes in the coding scheme, and then for all tape transcripts to be merged into a single database. This database then contains an infinitely cross-indexable record of how the Model-It software was used in the classroom, limited only by what codes were developed.

NUD*IST software was then used to query the database, for example, to show all instances across all pairs where a certain scaffold occurred in the Build mode, on the first day of use. When using this technique to get rough frequency counts, the researcher must still examine each coded segment to determine how many instances of a scaffold occurred, it is not automatic. Since the basic unit of analysis in NUD*IST is the line of text, a ten line conversation might have been coded as Teacher-Conceptual, resulting in ten lines with that code, but this might be just a single instance. Additionally, NUD*IST can generate reports of all text segments containing various criteria codes, so one might, for example, print out every instance of a certain scaffold and check the transcripts to see what occurred immediately before or after. Finally, one can generate multi-column reports where the use of, say, 7 tool scaffolds can be tracked day by day, or the use of certain tool scaffolds can be compared for conjunction with certain modeling strategies.

When graphing tool use patterns, counting scaffolds, and determining success of the scaffolds (below), in most cases the data comes directly from the transcripts. In certain instances, a longer conversation (of multiple text lines) will be counted as a single instance of scaffolding (the same as a one line comment). When determining if a scaffold was successful,

evidence was sought that the scaffolding produced no action or result. The standard was some degree of temporal conjunction or some specific reference later on. Examples: Teacher suggests learners save model, learners do not save in the next two minutes, scaffold is marked as not successful. Teacher discusses how to work factory into water quality model (acid rain), learners discuss something else for 3 minutes, return to factory issue, mention "what she said" and integrate acid rain into model, scaffold is marked as successful.

4.0 FINDINGS

4.1 Introduction

Detailed analysis of the process video tapes allows the examination of tool scaffolds, and the nature of scaffolding provided by teachers and peers. A variety of techniques are used to examine the results of NUD*IST queries. A variety of formats are used to display data gathered from the NUD*IST database. Summaries are made with text, numbers, and graphic charts to show how various scaffolds were used by the 6 pairs over the three days. In some cases, reexamination of the original video tape was undertaken, based on time marks pulled from the database. Database transcripts are examined in detail for evidence of what happens after each coded instance of some scaffolds.

4.2 Question 1 – What scaffolds in Model-It are used effectively?

A total of seven specific tool scaffolds are identified in Model-It and coded for in the database. Not all will be discussed here, partly for space constraints, and partly because some tool scaffolds were not documented in sufficient number as to provide a meaningful picture of use. Of the seven tool scaffolds identified and coded for, three are examined in detail. Four were not examined either due to lack of data or other complications that will require further refinement of methods to present in a meaningful way. The specific scaffolds examined were:

Tool (3 1 1) Linear Process Map

Tool (3 1 3) Qualitative/Quantitatuve in relationships Tool (3 1 4) Because/Description statements (Mandatory)

4.2.1 – Tool Scaffold 3.1.1, Linear Process Map

The Linear Process Map is a primary scaffold in Model-It and breaks the modeling process into three modes, to allow the learners to master the process in steps and to reduce the complexity of the modeling task. By breaking the task into three modes "Plan, Build, Test", the learner is presented with a constrained set of choices, and must, for example, first create an object to begin the model (there is no point in trying to test, or dealing with testing options, before an object has been created). In order to assess the use of this scaffold we will examine how the learners used the tool.

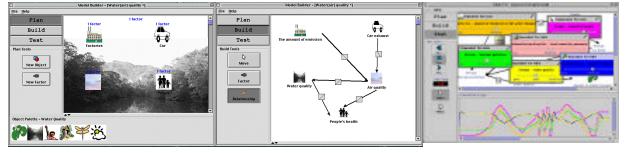
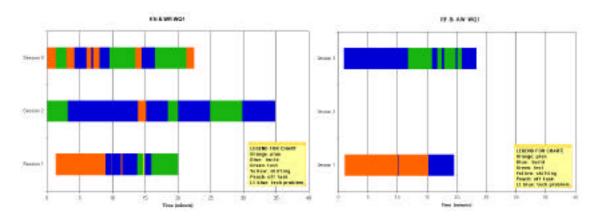
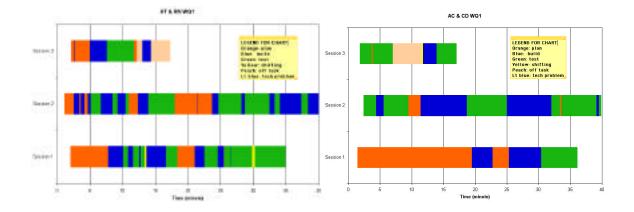


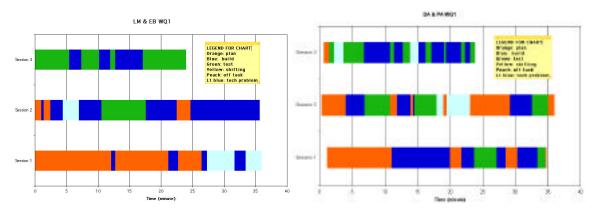
Figure 4.2.1 The Linear Process Map (Plan/Build/Test modes, buttons in upper left)

In Figure 4.2, one can see a graphical representation of how the tool modes were used (time marks were pulled from the NUD*IST database and exported to an Excel chart). Looking at each pair starting with the lowest bar (first use) on each chart, there is a clear tendency to start in Plan and Build modes, and to remain in these modes for longer periods of time during the first exposure. A more holistic description of each pair, by day, can be found in Appendix D. Over the three days the pattern shifts markedly to spending more time in Test mode, and shorter times in any given mode. The use of tool scaffolds shows a mixed pattern of use by pair, with some tendency toward fewer tool scaffolds in day 3.

FIGURE 4.2 SUMMARY Charts of Model-It Usage, Days 1 through 3.







Note: The bottom row of each chart is day one, progressing to day three on top. Colors indicate what mode of the Model-It program the pair was in, for what length of time. "Shifting" (yellow) is when learners jump from mode to mode quickly, without making purposeful effort in any one mode.

In table 4.2, below, one can find totals for scaffold uses by pair, by day. In this case, we are concerned only with reading across the "Tool" rows, to see the total number of tool scaffolds used, and the number of those that were not mandatory codes resulting simply from use of the interface. As discussed earlier, some scaffolds are coded based on the use of the tool (such as manipulating a meter) whereas others require explicit discussion (such as students debating about what type of relationship to use when presented with text and graph in the relationship editor). So, the number of non-mandatory scaffolds is important to consider as it represents a different type of evidence. Tool scaffolds are most common in the Day 1, which is to be expected as there are more scaffolds relevant to creation of objects, factors, and relationships.

Table 4	Table 4.2 SCAFFOLDS USED OVER FIRST THREE DAYS						_
	Day 1	Day 1	Day 2	Day 2	Day 3	Day 3	
Pair	# of	# Ignored	# of	# Ignored	# of	# Ignored	NOTES
	Scaffolds		Scaffolds		Scaffolds		
DA &	Tool 9(5)		Tool 7(7)		Tool 8(7)		Technical
PA	Teach 12	[0]	Teach 11	[0]	Teach 8	[0]	problems day
	Peer 8	[0]	Peer 2	[0]	Peer 1	[0]	1&2
LM &	Tool 3 (0)		Tool 3(2)		Tool 4(4)		Technical
EB	Teach 8	[0]	Teach 12	[0]	Teach 12	[2]	problems day 1
	Peer 9	[0]	Peer 0	[0]	Peer 0	[0]	
RF &	Tool 3(1)		Data	Data	Tool 5(1)		Day 1 short (20
AW	Teach 4	[0]	Not	Not	Teach 4	[01	min)
	Peer 2	[0]	Available	Available	Peer 2	[0]	_
WR &	Tool 10 (3)		Tool 11 (3)		Tool 9(5)		Day 1 short (20
KN	Teach 6	[2]	Teach 10	[1]	Teach 5	[1]	min)
	Peer 4	[0]	Peer 6	[0]	Peer 3	[1]	
AT &	Tool 22 (9)		Tool 19(19)		Tool 4(0)		AT solo day 1
RN	Teach 22	[2]	Teach 20	[0]	Teach 5	[0]	
	Peer 0	[0]	Peer 7	[2]	Peer 3	[0]	_
AC &	Tool 24 (3)		Tool 18 (2)		Tool 2 (0)		-
CD	Teach 13	[3]	Teach 8	[0]	Teach 5	[1]	
	Peer 4	[0]	Peer 1	[0]	Peer 0	[0]	_

 Table 4.2
 SCAFFOLDS USED OVER FIRST THREE DAYS

() = number of tool scaffolds that were NOT mandatory codes [] =not followed by related activity / successful scaffold Example: Day 1, pair DA&PA, they used tool scaffolds 9 times that day, and five of them were tool scaffolds that required them to do more than just use the tool (i.e. talk about using). They received 12 incidences of teacher scaffolding and all were followed by some purposeful action related to the scaffolding. Similarly, they scaffolded each other 8 times, and each was followed by some purposeful action (i.e. "we need to add a factor for acidity" and they then go to Build mode and do just that). 4.2.2 - Tool Scaffold 3 1 3 Qualitative/Quantitative Relationships

This scaffold allows learners to use default, qualitative relationships that do not require mathematical equations to specify the relationship. This scaffold also attempts to make possible the selection of more quantitative relationships if the learners desire. The relationship editor puts the factors in an explicit order, in the form of a sentence, that the students can read as a proposition, and then change the degree and direction. Example: "As water temperature increases, fish population (increases/decreases) by (more and more, a lot, a little, a bell curve)".

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Figure 4.2.2 The Relationship Editor

By reviewing the first three uses of this scaffold by each pair, we can gain an understanding of how this scaffold is used, employing the scaffolding assessment rubric of Quintana and colleagues (2000). This rubric involves six terms:

 Initial Accessibility 	Efficiency:	 Accuracy: 	 Progression: 	Reflectiveness:
Involves a "yes/no"	Measures how fast	Measures whether a	Measures how learners	Measures the amount of
answer to show	learners use a	scaffolded feature	progress through their	reflecting that a learner
whether learners can	particular scaffolded	supports the correct	work tasks while using a	performs while using a
access or use a	feature and how their	and appropriate	given scaffolded feature	scaffolded feature. This
scaffolded feature. If	performance changes	"doing" of a work task	to see if they work in a	describes whether the learner's
a scaffolded feature is	over time to see if the	and whether the	linear step-by-step	cognitive focus is on their work
not usable or	software might be	learner's accuracy	manner (i.e., a novice	tasks and how their reflection
accessible, then the	interfering with the	improves over time to	workstyle) or in a more	varies over time.
feature should be	completion of their	see if additional work	opportunistic, iterative	
redesigned.	work tasks.	support is needed.	style over time.	
-			-	

When the first three instances of learners using this scaffold are located by transcript and then examined on the original process video tape, it is apparent that all learners use this scaffold immediately and accurately. Progression is not an effective measure of this scaffold, because Quintana's (2000) work focused on scaffolding larger processes and this is a more constrained task. In table 4.2.2, we see that each pair of learners generally used the scaffold more quickly with each use, and we also note (unfortunately) that a scaffold within the relationship editor (the

text box where learners are supposed to justify their relationship choices) often goes unused. This explains the shorter time for learners with "no description". If one disregards the time to type in the description, this scaffold is used very similarly by each pair.

Table 4.2.2 First Three Oses of Relationship Scarfold								
	Use 1		Use 2		Use 3			
Pair	Efficiency	Reflectiveness	Efficiency	Reflectiveness	Efficiency	Reflectiveness	NOTES	
DA &	22 sec	Read sentence	17 sec	Read sentence	10 sec		Not using text box.	
PA	no descr	slowly	no descr	slowly	no descr			
LM &	10 sec	Read sentence	5 sec	Read quickly	4 sec	Read quickly	Created in 1 min.	
EB	no descr	slowly	no descr		no descr		sequence.	
RF &	Data Not	Data Not	Data Not	Data Not	Data Not	Data Not	No use day 1.	
AW	Available	Available	Available	Available	Available	Available	Day 2 no video.	
WR &	Not	Discuss need to	9 sec	Reversed first	8 sec	Side discussion	Caused revision to obj.	
KN	completed	change fac/obj	no descr	attempt	no descr	of degree	names	
AT &	42 sec		65 sec		25 sec		AT solo day 1.	
RN	(desc = 30)	No discussion	(desc = 50)	No discussion	(desc = 15)	No discussion	Loses desc w/ change	
AC &	45 sec		30 sec		28 sec			
CD	(desc = 30)		(desc = 20)		(desc = 18)			
F 1 F	E-marker Devil and DAR DAR devices b 22 and the second s							

Table 4.2.2 First Three Uses of Relationship Scaffold

Example: Day 1, pair DA&PA, they took 22 seconds to use the scaffold, reading the sentence layout slowly out loud, but failed to enter a description in the related text box. So they used one scaffold to create the relationship, but ignored another that sought to help them articulate their reasoning.

4.2.3 - Tool Scaffold 3 1 4 Descriptions/Because statements

This scaffold is designed to encourage learners to articulate their reasoning when creating objects, factors, and relationships (Figure 4.2.3 below). Each window for creating this items has a text box for entering this information. Table 4.2.3 summarizes 72 NUD*IST queries locating every time a learner created an object/factor/relationship and seeing how many of these cases had associated scaffold use, so we can get an idea of how well learners are using this scaffold. Transcripts are examined line by line to determine if discussion and text entry in the box occurred, if none did, then the scaffold is marked as "ignored".

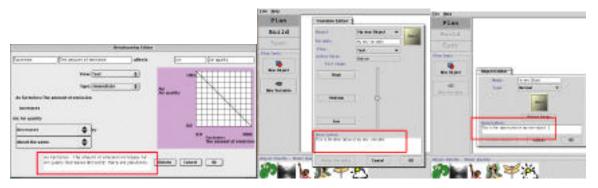


Figure 4.2.3 - Text boxes in relationship/factor/object windows.

							-
	Day 1	Day 1	Day 2	Day 2	Day 3	Day 3	
Pair	# of text	# Ignored	# of text	# Ignored	# of text	# Ignored	NOTES
	boxes		boxes		boxes		
DA &	4/7/0/9 = 20	2/7/0/7 = 16	4/8/0/11 =23	4/8/0/11=23	0/0/0/4 = 4	0/0/0/4 = 4	Technical probs
PA							day 1/2
LM &	3/3/0/4 = 10	0/0/0/4 = 4	0/0/2/10=12	0/0/2/10=12	0/0/0/0 = 0	0/0/0/0 = 0	-
EB							
RF &	3/6/0/0 = 9	3/6/0/0 = 9	Data	Data	0/0/0/5 = 5	0/0/0/0 = 0	-
AW			Not	Not			
			Available	Available			
WR &	4/3/1/2 = 10	2/3/1/2 = 8	0/2/0/4 = 6	0/2/0/0 = 0	5/5/0/7 = 17	5/5/0/0 = 10	-
KN							
AT &	4/5/1/9 = 19	0/0/0/0 = 0	1/3/0/9 = 13	0/0/0/1 = 1	1/1/0/1 = 3	0/0/0/0 = 0	AT solo day 1
RN							
AC &	4/11/0/6=21	0/2/0/0 = 2	0/1/0/7 = 8	0/0/0/0 = 0	0/0/0/1 = 0	0/0/0/0 = 0	-
CD							

Table 4.2.3 Use of Description/Because statements

Positive evidence is noted in green, negative (failure to use) is noted in red.

Example: Day 1, pair DA&PA, they were presented with 20 opportunities to fill in text boxes, four "create object", seven "create factor/plan", zero "create factor/build" and 9 "create relationship", for a total of 20. They ignored the vast majority of them (2 of 4, 7 of 7, and 7 of 9). Example: day 3, pair AC&CD, they only saw one text box, "create relationship" and they did fill it in.

We see that some pairs ignored almost all scaffolds, some pairs used almost all scaffolds, and others tended to ignore certain scaffolds, (e.g., fill in all relationship text, ignore all factor/object text). The two bottom pairs, the best users of the scaffolds, were from the same class, leading to curiosity as to whether the teacher might have been providing task scaffolding to fill in these scaffolds, however, a NUD*IST query showed that all three teachers provided just one or no reminders of this nature, and were essentially the same in this respect.

4.3 Question 2 – Teacher and Peer Scaffolds

When considering teacher and peer scaffolds, one can first examine table 4.2 and appendix D to gain an understanding of how these scaffolds are used by each pair, day by day. Table 4.2 shows the total number of scaffolds provided by teacher and peer for each pair by day. Since a prime concern is if the scaffolds were actually used, an examination of the transcripts was undertaken to see what happened after each instance of teacher scaffolding, to determine how often this scaffolding was resulting in some sort of purposeful action by the learners. The numbers in brackets [#] indicate how many, of the total provided scaffolds, were ignored or resulted in no purposeful action. Overall, the numbers are higher for teacher scaffolds, with greater variety of the five types, with some teacher scaffolds present for every day for every pair.

When considering peer scaffolds, a similar set of concerns and techniques are relevant. Peer scaffolds were examined by total number and also for how often the scaffolding was resulting in some sort of purposeful action by the learners. While the teacher and peer scaffolding have identical coding and criteria, peer scaffolding was far less common, varied, and consistent. There seemed to be a similar degree of "ignored" scaffolds from peers, when taking into account the larger number of teacher scaffolds.

4.4 Question 3 – Changes over time

When examining the scaffolds from tool, teacher, and peer above, the same data can be used to form an impression of how these scaffolds are used differently as learners spend additional days using the tool in context. Drawing on appendix D and table 4.2, we can make the following overall assessments.

Most pairs spent long periods of time in Plan and Build on day 1, with most using Test mode at least one short period on day 1. Tool scaffolding (mandatory) was heavy, as was peer and teacher conceptual scaffolding as the model was developed and discussed. Tool scaffolds were grasped easily, and were used more efficiently as time went on.

Day two was less standardized, with pairs starting variously in all three modes. Some continued to mostly construct (in Plan and Build), with short periods of test, while two spend half or more of their time in Test mode. Peer scaffolding occurs mostly in groups where model construction is most active. Teacher scaffolding of all types continues, with conceptual being the most frequent, and happening most in Test mode.

Day three showed a higher emphasis on Test mode in all pairs. Peer scaffolding dropped off, and did not occur at all in some groups. Teacher scaffolding was variable, with groups that were rigorously testing and tweaking their model getting conceptual scaffolding, while other groups that had "coasted to a stop" did not seek or get much teacher interaction.

5.0 DISCUSSION

5.1 Introduction

Several larger issues are quite clear from the analysis of this limited slice of data from the three classrooms. Modeling is a complex task, and while learners are able to quickly use the Model-It software, there is considerable variation in how learners use the tool, and how they pursue their modeling tasks. A case can be made that patterns of tool and scaffold use change over time, that teacher scaffolding is a vital aspect of the use of this software in classrooms, and that peer scaffolding is less vital but seems to vary in importance from pair to pair. This involvement of teacher and peer scaffolds is particularly of note since this version of Model-It did not contain as many prompts (as previous versions) for saving work, testing, or filling in text boxes, yet both teachers and peers frequently provided this prompting. Overall, there is still a difficulty in knowing what exactly the learners are thinking, so that explicit uses of the tool are easy to code, but most of the rest of the analysis depends on learners vocalizing explicitly. Even with these concerns, a number of conclusions can be reached.

5.2 Tool Scaffolding

There is considerable evidence that some of the tool scaffolds are functioning as designed. Those cases where evidence is missing or as yet not analyzed may be due more to the

complexities of gathering data, rather than any failing of the tool. For the three tool scaffolds

examined in this study, we see:

3. 1. 1 Process Map	3. 1. 3 Qualitative/Quantitative	3. 1. 4 Because/Description.
We see the desired effect, learners quickly engage the program, create structure in the Plan mode, add to it in the Build mode, and then debug/refine the model using the Test mode.	Learners use the scaffold immediately and accurately. Efficiency is adequate for first use and increases with each use. (Some groups faster still due to failure to use text boxes).	Use is variable by pair. Some use almost all these scaffolds, others use almost none of them. There may be an "expedience" issue, with some learners simply regarding the scaffold as an impediment to rapid model completion.

5.3 Teacher/Peer Scaffolding

Teacher and peer scaffolding play a significant role in the use of the Model-It software in context. Teacher scaffolding in particular is a vital part of the use of Model-It in classroom this classroom context. Teacher provide scaffolding for using the tool and thinking conceptually of the model (most common), for addressing content knowledge gaps, as well as reminding learners to save, fill in descriptions, and think about strategies. These scaffolds are seen with every pair, across every day of use. While found in every mode, the greatest frequency, and longer discussions occur in Test mode, when learners are demonstrating and debugging their models. While some of what teachers provide (prompts to save, test, increase/reduce complexity) could be handled by prompts built into the tool, the conceptual and strategy scaffolding provided by teachers is both irreplaceable (at this stage of AI programming) and invaluable. Not all teacher scaffolds result in purposeful action by the learners, but the vast majority do. Many of those ignored were of generic nature (i.e. "save now") and often not addressed to a specific pair.

Peer scaffolds show a reduced diversity and frequency when compared to teacher scaffolds. These scaffolds tended to vary widely depending on the pair's social style. In general, the majority of peer scaffolds were conceptual (proposing additions to model) or utility (prompts to save or test). As with teacher scaffolds, most peer scaffolds did result in purposeful action, and when they were ignored, often it was due to the learner proposing the action not having control of the mouse and the other learner wishing to pursue an alternate strategy. Peer scaffolds seem to be the least important of the three types, yet evidence clearly suggests they play a role in using the software to create a model. A significant burden of "question and answer" seems to be removed from the teacher by peer's assistance, and additionally, peers provide considerable input on content and conceptual structure of the model.

5.4 Changes over time

There is some evidence for change in scaffold use over time, but clearly further inquiry is needed. Certain tool scaffolds are used more efficiently over time, and clearly the usage of the tool modes changes from day 1 to day 3 (as desired). Teacher scaffolds, particularly conceptual, tend to occur more often in Test mode, which occurs more often in later days. Peer scaffolding drops off from day 1 to day 3. Beyond these clear trends, the data do not really support additional conclusions, but with further data collection from additional classes and grades, a more comprehensive view of changes over time may emerge in the future.

5.5 Directions for Future Research

When reviewing this study, a number of opportunities for future research suggest themselves. First, within the ongoing research, there are additional data sources that might be considered. Classroom video, learner artifacts, and pre/post interviews can be examined to make stronger arguments about results of the observed trends in scaffold use. For example, if a pair tends to use less teacher scaffolding, and ignores the tool scaffolds for articulation, is there a resulting lower quality of their model? Additionally, as the research progresses, an opportunity will arise to examine the same learners across two years of using the same tool, so a longitudinal examination could be made of various factors.

In terms of additional research, conducting this research in other school contexts (lower SES, larger class size, etc) would provide either interesting confirmation or revision to the results observed here. One might also conduct more explicitly experimental research on versions of the software tool that contain or do not contain specific scaffolds, or environments were teacher/peer scaffolds are controlled in some way (particularly for first time use) to refine the ideas of what seems most important from this study. Lastly, a refined coding scheme or standards, or a more explicit think aloud protocol, might provide data on the tool scaffolds that thus far have not been assessed.

6.0 SUMMARY

A case was made for the value of the modeling task in science education, the use of dynamic modeling software for modeling, and the need for scaffolds to assist learners in this effort. Theoretical backgrounds for thinking about scaffolding were discussed, as were methods used to assess scaffolding. A combination of methods were used to examine scaffolding in Model-It, as well as the teacher and peer scaffolds occurring around Model-It use in context. Evidence was presented (with the assistance of NUD*IST qualitative software), to show that some, but not all scaffolds were used successfully, and that teacher and peer scaffolds do interact importantly with tool scaffolds in classroom contexts. There is also some evidence for changes in scaffold use over time. Further research is clearly indicated, and options for this were discussed.

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