Int. J. Engng Ed. Vol. 24, No. 4, pp. 783–793, 2008
Printed in Great Britain.
0949-149X/91 $3.00+0.00
© 2008 TEMPUS Publications.

Developing a Practical Tutoring Model Based on Elements in Naturalistic Tutoring and Cognitive Theory*

STEVEN C. ZEMKE[1] and DONALD F. ELGER[2]
[1] *School of Engineering, Gonzaga University, AD-0026, 502 E Boone Ave., Spokane, WA 99258–0026, USA. E-mail: zemke@gonzaga.edu*
[2] *Mechanical Engineering Department, Engineering Physics Building, University of Idaho Moscow, ID 83844, USA. E-mail: delger@uidaho.edu*

In engineering education, one-on-one tutoring is commonly used to stimulate learning. This study develops and refines a practical tutoring model. The model is based on naturalistic tutoring augmented with elements from cognitive theory that are specifically missing in naturalistic tutoring. A four-week case study of near-peer tutors in engineering dynamics suggested four findings. First, interactions should be based within the tutee's cognitive framework. Second, deep exploring of the tutee's pre-existing knowledge leads to tutoring within the tutee's cognitive framework. Third, four tutoring actions emerged that address learning needs while keeping the tutoring within the tutee's framework. These tutoring actions are: a) guided assistance in problem solving, b) prompting tutees to construct and reconstruct what they know, c) explicit problem structuring and, d) presenting new information only when needed. Fourth, deep exploring facilitates the development of strong rapport. The paper concludes with a presentation of a revised tutoring model.

Keywords: tutor; tutoring model; cognitive; naturalistic tutoring; engineering

CONVENTIONAL WISDOM suggests that individualized tutoring greatly enhances learning; indeed many studies have confirmed this wisdom. The increase in learning from naturalistic tutoring, that is tutoring in a natural as opposed to a laboratory setting, is frequently called the 'two sigma effect', which indicates that the average learning by tutoring is two standard deviations higher than learning in traditional lecture classes.

The two-sigma effect, however, is a generalization. Measured effect sizes vary from 0.4 to 2.3 [1, 2, 3]. Further, each specific instance of tutoring has no guarantee of mediating increased learning.

The benefits of tutoring cannot be attributed to tutor training. Most tutors have brief or even no training [2]. In spite of this, tutoring is effective. However, the effectiveness spans a large range (0.4 to 2.3 standard deviations) indicating that some tutors are more effective than others. Consequently, there is ample opportunity for many tutors to increase their effectiveness.

It seems reasonable that training in a few 'tutoring essentials' may greatly improve some tutors' effectiveness. What are these essentials and how can they be conveyed in a simple and effective way? Many texts on tutoring [4, 5, 6] suggest tutoring models constructed on rapport building, pedagogical methods and practical tips are the answer. These texts represent a wide variety of perspectives. The intent of this present study is to identify some tutoring essentials from a *cognitive* perspective. These essentials are described in terms of a tutoring model (hereafter simply called 'model') that forms the foundation for brief tutor training. The structure of this case involved creating an initial model, using the model with tutor-tutee pairs, gathering evidence on the workings of the model and refining the model based on evidence.

The initial model is based on dialogue patterns that mediate learning in naturalistic tutoring. These patterns are then augmented with guidelines designed to counteract deficiencies also found in naturalistic tutoring. This combination may predispose tutors to embody effective qualities of naturalistic tutoring but avoid common pitfalls. The complexity of the model is kept to a minimum to make it easier to follow. Further, since portions of the model mirror what untrained and briefly trained tutors do, it is expected that tutors in training will find the model easy to follow. Since the original use of this model was in a near-peer academic mentoring programme [7] in the Mechanical Engineering Department at the University of Idaho (UI) the development of rapport was also of interest.

The model will be examined along the following four questions:

1. How did the tutors interpret and implement the model?
2. What actions did the tutors consider important?

* Accepted 11 July 2007.

3. What mediated learning from the tutees' perspective?
4. How did rapport develop?

CREATING THE INITIAL MODEL OF TUTORING

The initial model is based on two areas of literature: cognitive studies of learning in general, primarily as described by Bransford *et al.* [8] and Donovan *et al.* [9] and cognitive studies of naturalistic tutoring. The following subsections describe the findings in these areas that are incorporated into the initial model.

Fertile Ground for Learning: the Tutee's Representation of Knowledge

Many studies have shown that learning is an active cognitive process. Rather than merely assimilating information, the learner is literally reconstructing it [8, 9]. This cognitive processing is strongly preconception driven, that is, learners attempt to understand new knowledge in relation to their pre-existing knowledge. 'Learners actively construct their understanding by trying to connect new information with their prior knowledge . . .' [10].

As a person is learning, his or her understanding is changing. We define an individual's representation of knowledge (hereafter simply called 'representation') as the current state of the individual's knowledge, correct or incorrect, in terms of content and organization. An individual's representation therefore contains all of the individual's preconceptions that drive learning.

Given that tutees understand new knowledge (correctly or incorrectly) based on their pre-existing knowledge, it seems fundamental for tutors to frame their words from their tutees' perspectives. Consequently, the initial model directed tutors to work always within their tutee's representations. Though this seems reasonable, it should be noted that this may represent a frustration for the tutor. For example, when a tutee 'just doesn't get it at all', it may seem more straightforward to simply 'tell the tutee what is right and why'. However, in such an explanation the tutor is actually asking the tutee to simply set aside his or her representation and somehow 'adopt' the tutor's representation while working on a problem.

Collaborative Dialogues and Iterative Learning

Graesser, Person and Magliano [11] analysed dialogue patterns from 44 tutoring sessions of undergraduates and 22 sessions of seventh grade students. The analysis identified whether elements of eight different pedagogical practices were evident in the dialogues. Three elements were evident: anchoring learning in specific examples, collaborative problem solving and deep explanatory reasoning. Five elements were not evident: active student direction of learning, sophisticated pedagogies, convergence toward shared tutor-tutee meaning, feedback with remediation and affective based motivations. The analysis also identified a common five-step dialogue pattern:

Step 1: Tutor asks question.
Step 2: Student answers question.
Step 3: Tutor gives short feedback on the quality of the answer.
Step 4: Tutor and student collaboratively improve the quality of the answer.
Step 5: Tutor assesses student's understanding of the answer.

The majority of the learning was traced to step four, 'tutor and student collaboratively improving the answer'. In other words, learning was primarily embedded in collaborative interactions, rather than in the tutor's or the tutee's actions independently.

Chi *et al.* [12] found that tutor and tutee statements that were primarily independent actions (and hence non-collaborative) mediated little learning. For example, lengthy tutor explanations correlated with learning of only shallow knowledge (piecemeal information). Conversely, the tutees showed little active engagement in the learning and hence produced few independent actions.

Our initial model directed the tutors to initiate collaborative tutor-tutee conversations that iteratively improved their tutees' understanding. Since this type of dialogue mediated learning in the natural setting, it seemed reasonable to prescribe it in our model.

Tutor and Tutee Shared Understanding

Though tutors and tutees frequently engage in collaborative problem solving, Graesser noted [11], 'Tutors and tutees typically do not come to a shared understanding, but operated in very different worlds'. Tutors were typically poor at understanding tutees' misconceptions. Chi *et al.* [13] found that though tutors adequately diagnose missing information and simple errors in structural knowledge, they typically do not diagnose larger structural errors. Furthermore, the tutors routinely overestimated what the tutees knew correctly and underestimated what the tutees knew incorrectly [13].

The lack of awareness of tutee incorrect understanding is a clear deficiency in many naturalistic tutoring sessions. This lack of awareness puts the knowledge being learned at risk. The opportunity to learn is also at risk if the lack of awareness involves incorrect preconceptions. Further, unseating incorrect preconceptions is difficult even when contradictory knowledge is taught [10]. To address this need Bransford *et al.* [8] recommend, 'Teachers must draw out and work with the pre-existing understandings that their students bring with them'. Consequently one class of tutoring actions prescribed in the initial model was for the tutor to spend significant time prompting the tutee to discuss his or her understanding. The primary aim of this prompting was to increase tutor and tutee awareness of the tutee's understanding.

Tutor Led Actions

Graesser *et al.* [11] identified several tutor actions such as splicing answers, hinting, summarizing and elaborating that mediated learning. Tutoring interactions also contain co-construction of scaffolded explanations [14] which may lead to learning since self-explanations have been linked to learning in other studies [15, 16, 17].

As stated earlier, lengthy tutor explanations correlated with learning of only shallow knowledge. To decrease tutor explanations and increase collaborative dialogue, Chi *et al.* [12] directed tutors to substitute open-ended content-free prompts for explanations. Such prompts as 'What could you learn from this sentence?' or 'Why do you think so?' were given to the tutors to use. The tutors used the content-free prompts about 25 per cent of the time and added context specific content to the prompts the remainder of the time. As expected, tutor-given explanations greatly decreased and were replaced by interactive dialogues. The tutees learned just as effectively in this environment and there was some evidence that deep learning increased. This finding is reinforced by the observation that expert tutors typically do not provide explanations or answers [18].

Collaborative tutor actions such as hinting, splicing answers, elaborating, and prompting tutee responses seem complementary to tutee construction of knowledge. Inevitably, as a tutee constructs knowledge he or she encounters various difficulties. These tutor actions may allow the tutee to overcome difficulties and continue constructing knowledge. Consequently, the initial model explicitly directed tutors to use actions that helped tutees construct knowledge in place of lengthy explanations.

The Preliminary Model of Tutoring

Previously we have prescribed four aspects of the tutoring model. They are set out below and reframed in terms of the model (Fig. 1).

1. The tutor's overarching goal is to focus all actions within the tutee's representation. Practically, this means: a) all tutor actions are referenced to and understandable from the tutee's pre-existing knowledge (correct or incorrect), b) the tutor willingly works to correct tutee misconceptions and c) the tutor avoids lengthy explanations. This goal seeks to align tutor actions with tutee knowledge construction.

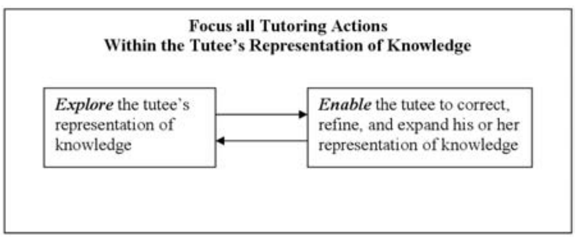

Fig. 1. The preliminary model of tutoring

2. Two broad classes of tutor actions are shown in the boxes. The first class of actions is to explore the tutee's representation of knowledge. Exploring entails prompting the tutee to discuss his or her representation. The primary goal of exploring is to surface a rich understanding of the tutee's pre-existing knowledge. Prompts such as, 'Please explain to me how you understand this', or 'How do you think we could solve this?' are used to explore. Exploring may begin with general questions, but must follow through to deeper probing.
3. The second class of actions is to enable the tutee to correct, refine or expand his or her representation. When a tutee's misconceptions and inadequate understandings are surfaced, the natural response is to address them. For an action to be enabling it must, a) focus primarily within the tutee's representation and b), support tutee construction of knowledge. Actions such as redirecting the tutee's attention, prompting the tutee to reason aloud or prompting the tutee to connect concepts are considered enabling. Tutor actions such as direct explaining or telling are not considered enabling.
4. The two opposite pointing arrows indicate that the collaborative dialogue should iterate between exploring and enabling.

It should be noted that working within the tutee's representation, surfacing a rich understanding of that representation and working within it are difficult goals. Since the tutor's understanding of the tutee's representation cannot be complete, it is reasonable to expect the tutor to fall short of the goal. However, it is also reasonable to expect the tutor to work more closely within the tutee's representation if that is one of the tutor's primary aims.

STRUCTURE OF THE CASE

The case had a threefold purpose: train the tutors to practice the model, encourage the tutors to refine their practice and collect evidence to understand the functioning of the model. We structured practice, reflection and planning into the tutors' regimen to meet these purposes [19, 20]. The bounded case [21, 22] involved six tutor-tutee-observer trios that remained intact for the four-session study. Six junior and senior engineering students within the UI mentoring programme served as tutors for six sophomores taking engineering dynamics. Six additional undergraduate mentors served as observers.

Before the first tutoring session, the tutors and observers practiced exploring and enabling in three one-hour training meetings. The training involved role playing and group discussion of effective ways to implement the tutoring model. Working within the tutee's representation was emphasized in each training meeting.

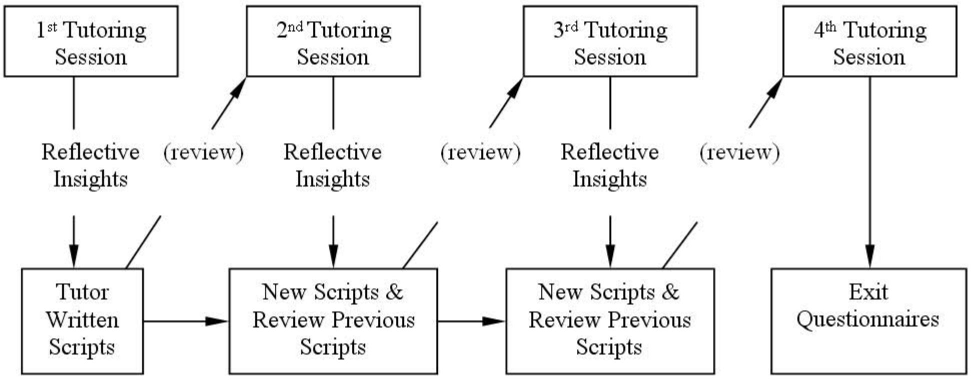

Fig. 2. Structure of the four-week case.

In the first tutoring session, the tutor-tutee pairs worked on tutee-chosen problems for thirty minutes while the observers took notes. After the session, the tutees completed short questionnaires and were excused. Concurrently, the tutors recorded self-reflective notes about the session. Each tutor-observer pair then discussed what happened during the session and how the tutor could improve his or her performance. After the discussion, each tutor wrote up to three scripted responses to improve tutoring. Each scripted response began with a tutor selected cue such as, 'The next time I notice the tutee is lost . . .' and finished with a tutor- planned response such as, '. . . I could ask, "what is puzzling you?"'

The tutors began each successive session by reviewing their scripted responses. The sessions then proceeded identically to the first. The final session concluded with the tutors and tutees completing exit questionnaires. Figure 2 diagrams the structure of the case.

All tutor and observer notes, weekly tutee questionnaires, tutors' scripted responses and end-of-study tutor and tutee questionnaires were retained as data. These data provide multiple perspectives, both explicit (surveys and questionnaires) and implicit (e.g. tutors' scripted responses), at multiple times throughout the study. Collectively these perspectives triangulate on the four questions investigated.

FINDINGS AND DISCUSSION

How did the tutors interpret and implement the tutoring model?

As expected, collaborative dialogues of exploring and enabling within the tutee's representation were evident. The tutors were directed to follow the model and indeed they did. However, the data revealed two types of exploring and four distinct means to enable. Other tutor actions were also evident.

The tutor and observer data represent different perspectives and biases. The tutors recorded their notes from memory so could not be other than biased when trying to remember more events from the beginning and ending of the sessions (serial position effect of memory, [23]). Tutor notes may also be biased in reporting intents rather than actions. In contrast, the observers would not be subject to memory biases. However, their role of giving the tutors helpful feedback could bias their notes. Both tutors and observers would be susceptible to recording bias caused by their following the tutoring model.

Tutor actions reported in the tutor and observer weekly notes were tallied in categories that emerged in the notes. Frequencies of these actions are listed in Table 1. The notes were of varying quality and led to less precise coding than desired. As a result, close differentiation between similar frequency tallies is not reliable. However, the general trends of the reported frequencies and the existence of all listed categories are trustworthy. Even given the varying quality of the notes, the relative frequency of actions reported by the tutors and observers is quite similar. Since the tutors and observers had different biases, the agreement in frequency adds credibility to the recorded actions [22, 24].

Exploring accounted for approximately one quarter of the recorded tutoring actions. These actions were split roughly equally between *shallow* and *deep* exploring. Tutor questions that elicited simple piecemeal information were coded as shallow exploring. Questions that elicited explanations including meaning or relational understanding were coded as deep exploring. Though the training sessions emphasized only deep exploring, the tutors engaged in both.

Approximately one-third of all actions were enabling, falling into four distinct sub-categories. Two tutoring actions, guided assistance and prompting refinement, accounted for most of the enabling actions. Problem structuring and infusing information were recorded at a much lower frequency.

The tutors typically worked problems collaboratively with the tutees. The tutees would do most of the work and the tutors would step in as needed. We define 'stepping in as needed' as guided assistance. Since this is framed by the tutee's solution to

Table 1. Weekly tutoring actions recorded in the tutor and observer notes

Category in Model	Sub-category of recorded observation	Tutor Notes (97 Responses)		Observer Notes (238 Responses)	
Exploring	Shallow Knowledge	10%	26%	14%	27%
	Deep Knowledge	16%		13%	
Enabling	Prompting Refinement	16%	36%	11%	39%
	Guided Assistance	16%		20%	
	Problem Structuring	3%		3%	
	Infusing	1%		5%	
Tutee's Representation	Tutor and tutee working in different representations	5%		2%	
Other	Directly explaining	5%		8%	
	Rapport building	13%		10%	
	Affirmative reinforcing of correct answer or response	2%		6%	
	Observing tutee	3%		3%	
	Tutor needs to master subject better before tutoring	6%		3%	
	Miscellaneous	1%		2%	

the problem, it is by nature within the tutee's representation. Furthermore, other tutor interventions in this context are referenced to the tutee's actions and are likely to be framed within the tutee's representation.

The tutors also frequently prompted the tutees to re-evaluate something they already knew. We label this prompting refinement. Since the tutees were re-evaluating their pre-existing knowledge, these prompts were within the tutees' representations. Prompting refinement is exemplified by this observer's note, '(the tutor) directed the tutee to make a distinct link between the problem and the equations'.

A few of the tutor actions involved providing an explicit solution structure for the tutee. We define this action as problem structuring. The initial problem structure certainly comes from the tutor's, and not the tutee's, representation. However, since the tutee proceeds to exercise his or her pre-existing knowledge within the structure, this action is considered enabling.

The tutoring action of infusing is best understood by contrasting it to explaining. We define explaining as a tutor supplying information referenced from the tutor's representation. In such an instance, the tutee needs to work from the tutor's representation to fully understand the explanation. In contrast, we define infusing as a tutor supplying information referenced from the tutee's representation. In practical terms, small pieces of knowledge presented at times when the tutee can immediately use them, are considered infused. Lengthy or out-of-context tutor explanations are considered explanations. The tutor and observer notes showed evidence of both in small amounts.

Working within the tutee's representation, the tutor's primary goal in the model, is also evident in the tutor and observer notes. All actions of exploring and enabling, as coded above, are within the tutee's representation and account for roughly 65 per cent of the recorded actions. A few specific instances of failing to work within the tutees' representations were also recorded. One observer noted, '(the) tutor at first had his own representation and was mixing the two (tutor's and tutee's representations). This confused the tutee and led him to say, "that's not what the problem is."' Mixing of the tutor's and tutee's representations appeared to impede learning.

The same tutoring actions identified in the tutor and observer notes, also emerged in the tutee questionnaire responses. The tutee questionnaire independently characterized the tutors' actions. The questionnaire asked an open-ended question concerning tutor exploring and another concerning tutor enabling of learning (Table 2). Since the tutees' biases differ from the tutors' and observers', the agreement of perspective strongly triangulates the results.

The first question, "What actions did the tutor take to understand the problem from your perspective?" was intended to diagnose how the tutors were exploring. The large majority of the responses indicated the tutors were asking for general explanations, "He asked me to explain to him what I thought." Some responses indicated the tutor used guided discussion, "He walked me through what I was doing . . ." and some indicated specific probing, "He asked me questions of what I know and don't know." The tutee responses also indicated deep exploring roughly twice as often as shallow exploring.

The tutors were obviously exploring both shallow and deep knowledge, but how effective were they? The tutee questionnaire asked the tutees to, 'Rate how much of the time the tutor seemed to understand the problem from your perspective' (five point Likert scale of 0, 25, 50, 75, 100 per cent). The aggregate response was split fairly evenly between 75 and 100 per cent with an occasional 50 per cent. This response suggests that effective exploring was taking place, but that the tutors were not fully working within the tutees' representations.

The second question, 'What actions did the tutor take to help you understand the problem better?' triangulates the enabling actions of the tutors. The tutee responses identified the same

Table 2. Tutor actions identified in coded weekly tutee questionnaire responses

Question 1: "What actions did the tutor take to understand the problem from your perspective?"

- Tutee misunderstood and answered different question . . . 5 responses, 21%
- Tutor was exploring shallow knowledge . . . 7 responses, 29%
- Tutor was exploring deep knowledge . . . 12 responses, 50%
- Tutees reported that 85% of the time mentors understood problem from their perspective.

Question 2: "What actions did the tutor take to help you understand the problem better?"

- Tutor provided guided assistance . . . identified in 29% of the responses
- Tutor provided problem structuring . . . identified in 24% of the responses
- Tutor was prompting refinement . . . identified in 24% of the responses
- Tutor was explaining . . . identified in 14% of the responses
- Tutor was infusing . . . identified in 10% of the responses
- Tutor was exploring deep . . . identified in 14% of the responses
- Tutor was exploring shallow . . . identified in 10% of the responses
- Tutees reported that 90% of the mentors' attempts to help actually helped.

tutoring actions of guided assistance, prompting refinement, problem structuring and infusing.

Tutee responses, like the observer and tutor notes, also indicate that the tutors were engaged in some explaining. Use of the tutee's representation is not apparent in comments such as, 'She showed me how to do the problem a different way'. Consequently, such comments were coded as coming from the tutors' own representation. Given that the tutors were exploring, some of the tutee responses coded as explaining may have been infusing. However, since the tutors' exploring was not complete, some direct explanations also seem reasonable to expect.

The second question also identified another dynamic of exploring. The tutees reported that tutor exploring helped them (the tutee) to understand the problems better. 'He told me to . . .explain to him what each part of the equations meant. That really helped because it is important to know how the equations work'. In essence the exploring itself helped the tutee to construct knowledge.

In summary, the tutors, observers and tutees all identified that the same tutoring actions were present and in similar proportion. The tutors were exploring both shallow and deep knowledge effectively, but not completely. The exploring not only directed the tutors' actions but at times directly helped the tutees to learn. The tutors implemented enabling, primarily by guided assistance and prompting refinement with lesser amounts of problem structuring and infusing. Most of the tutors' actions appeared within the tutees' representations of knowledge. However, in a few situations the tutors mixed their own representation with the tutee's representation which resulted in impeded learning.

What actions did the tutors consider important?

Several factors contribute to the trustworthiness of the tutor's perspectives. First, the tutors were aware, to varying degrees, of the tutees' progress and their affective responses while learning. Second, the tutors were engaged in a cycle of tutoring, reflecting, discussing the session, planning and testing improvements. This improvement cycle would deepen and clarify their perspectives. Third, the observers-tutor discussions added an external perspective to balance the tutors' self-reflections. Finally, the aggregate perspective represents six tutors over four sessions with many improvement ideas tested in practice.

The tutors' perspectives were identified in two ways. First, the tutor cue/response scripts were coded to surface underlying trends. These trends reflect what the tutors attempted to embody, and hence felt was important. Second, at the end of the study each tutor identified his or her most useful script and explained why it was most useful. The 'best scripts' established priority among the several scripts.

The cues in the scripts can be viewed as 'recognizable tutoring opportunities'. By creating, recording and reviewing these cues the tutors increased their awareness of situational intervention opportunities. The tutors estimated that they followed their scripts 75 per cent of the time.

Tutoring cues fell into two broad categories (Table 3). Seventy per cent of the cues were tutee focused and identified what the tutee was doing or had done. Typical cues of this nature were, 'The next time I notice the tutee is not starting . . .' or, 'The next time I notice an incorrect answer . . .' Tutee focused cues identified tutee procedural difficulties two and a half times as often as declarative know-

Table 3. Tutor cues from prompting planned responses

Cues—recognizable tutoring opportunities			
Tutee focus	Tutee's actions	17 = 45%	"The next time I notice the tutee is not starting . . ."
	Tutee's work products	10 = 26%	"The next time I notice an incorrect answer . . ."
Awareness	Self-awareness	6 = 16%	"The next time I notice I am generating the equations for him . . ."
	Situational awareness	5 = 13%	"The next time I notice we are stuck . . ."

ledge errors. The other 30 per cent of the cues related to awareness of self or situation. Typical cues of this nature were, 'The next time I want to follow my representation . . .' or, 'The next time I notice I am generating the equations for him . . .'

The planned responses in the scripts identify the tutors' view of how to capitalize on tutoring opportunities. The responses identified the same tutoring action as noted earlier (exploring, guided assistance, etc.) but reflected a different priority in proportions. Whereas the tutors, observers and tutees reported more enabling actions than exploring (Tables 1 and 2 above), exploring scripts outnumbered enabling scripts (Table 4 below). This shift indicates that the tutors were attempting to increase the amount of exploring. Another trend in the scripts was that exploring actions frequently preceded enabling actions. For example, 'The next time I notice an incorrect application of a concept I could response with, "Why is that so?"' both explore and prompt the tutee to refine his or her representation. Finally, one additional tutor action, that of suppressing natural responses, also emerged (Table 4).

The tutor-picked 'most useful scripts' also reflect an emphasis on increasing the amount of exploring. Strikingly, all of the most useful scripts included exploring. Three of the scripts were solely deep exploring. Another most useful script was deep exploring coupled to follow-on actions to create a mini-strategy. The final most useful script was shallow exploring to keep the tutoring consistent with the class. (One tutor did not identify a most useful script.)

In summary, each week the tutors planned and implemented improvement to their tutoring. Their improvement plans included the same tutor actions as before; however the plans emphasized employing these actions at more opportune times and in different proportions. Increasing the amount of exploring emerged as the predominant change in proportion of the actions, suggesting a higher value for exploring. The tutors' 'most useful scripts' included only exploring actions, further indicating a higher value on exploring.

What mediated learning from the tutees' perspective?

The end-of-study tutee questionnaire asked, 'What things did your tutor do that were especially helpful in learning the material and why were they helpful?' The responses provide insight into both learning needs and the tutoring actions to meet them. It seems reasonable that the tutees were aware of some, but not all, of their learning needs. It also seems reasonable that the tutees recalled helpful tutoring actions, but were unaware of beneficial tutoring actions that were not employed. Consequently, their perspective is considered true, though incomplete.

The tutee learning needs are inferred from their responses to the latter half of the question, ' . . .why were they (the tutor's actions) helpful?' In answering 'why', each of the responses referred to a basic learning need. Thus the tutees reported learning needs implicitly in context with specific tutoring actions. This reporting method avoided bias associated with directly asking the tutees to identify their learning needs.

Coding of the responses surfaced five broad learning needs that were serviced by seven tutoring actions. The responses map tutoring actions to learning needs, but not with a simple one-to-one relationship. Various tutoring actions were used to meet the same learning need and conversely each tutoring action could meet a variety of learning needs. The data also indicate that some actions were used together, such as exploring leading to infusing, to create mini-strategies. We conjecture that nearly all of the actions could be used in combination and frequently were. Figure 3 maps the tutoring actions to the learning needs showing the frequency of responses in parenthesis. The five learning needs: Guidance and monitoring, Solution path structuring, Missing information, 'Seeing' the big picture and Basic self-confidence are discussed individually below.

Five tutee responses identified a need for simple guidance and/or monitoring. The guidance or monitoring allowed the tutees to exercise their skills with the tutor stepping in as necessary. '(The tutor) provided assistance (by) helping during problems, checking my work, keeping me on track'. Guidance and monitoring were primarily provided by tutor actions of guided assistance, though shallow exploring and explaining were also employed to guide and monitor.

Four responses identified a need to have the problem broken into pieces or explicitly struc-

Table 4. Tutor planned responses

Responses—how to capitalize on tutoring opportunities				
Exploring	Shallow	12 = 24%	48%	" . . . What's the goal?"
	Deep	12 = 24%		" . . . Have him explain the solution to me."
Enabling	Problem Structuring	6 = 12%	40%	" . . . Break down each part of the equation concepts (KE, PE, etc.)."
	Prompting Refinement	5 = 10%		" . . . Why is this wrong? How do we know?"
	Guided Assistance	7 = 14%		" . . . Step in emphasizing the next step."
	Infusing	2 = 4%		" . . . Let's use the engineering process."
Suppressing natural responses		5 = 10%		" . . . Give the pencil back (to the tutee!)."
Giving positive support		1 = 2%		" . . . Good job, way to go . . ."

tured. As in guidance and monitoring above, solution path structuring allowed the tutees to exercise the skills they already had. Unlike guidance and monitoring, the tutor stepped in at the beginning and explicitly set the problem structure. '(He) broke the problem into parts and (we) analysed the parts independently. (This helped because I could) work through the parts one at a time'. Problem structuring was the primary tutoring action to meet this need.

Both guidance/monitoring and solution path structuring reduce complexity for the tutee while keeping the learning in context. Monitoring allows the tutee to generate the solution but not deal with error checking, staying on the right path, etc. Solution path structuring similarly reduces complexity, but does so explicitly at the beginning rather than during real-time. Taken together, reduction in complexity accounted for roughly half of the responses.

In contrast to reducing complexity, four responses identified a need to 'see' the bigger picture. Each of these responses contained elements of metacognition, that is, the tutee monitoring his or her learning or solution generation. 'He had me explain why I was using what I was using (so) I looked for better answers (and) this led to more efficient solution paths'. Gains in metacognition are associated with accelerated, deep and expert learning [8]. Deep exploring and/or prompting refinement were the primary tutoring actions to meet this need. Differentiating between these two tutoring actions was not possible in this specific data because a response such as, 'Please explain how the equations relate to the problem . . .' could be interpreted as either action.

Separate from either reducing or integrating complexity, five responses identified a need for basic information. The needed information included both declarative and procedural knowledge and spanned clarifying existing knowledge and presenting new information. The tutors provided the information by primarily infusing or explaining.

A single tutee reported a need for confidence to attempt the work. '(He) encouraged me with good comments (which) made me believe I could do the problem'. As noted earlier, encouraging comments were sprinkled throughout the tutoring actions. In this case apparently, the encouraging comments served more purpose than merely a social grace.

Considering the data from a perspective of which tutoring actions serviced which learning needs highlights the uses of various tutor actions. Guided assistance is the primary means to providing guidance and monitoring (obviously) but also services the broadest range of needs. Problem structuring was used only to structure solutions. Infusing and explaining were the primary means to providing missing information. Deep exploring and/or prompting refinement was the primary means to helping the student integrate a larger understanding or become metacognitive.

In summary, the tutee responses implicitly identified five learning needs and mapped the previously identified tutoring actions to meet them. Roughly half of the expressed learning needs involved reducing problem complexity. Guided assistance and problem structuring primarily serviced these needs. Gaining a larger picture accounted for a quarter of the learning needs. Deep exploring and/or prompting refine-

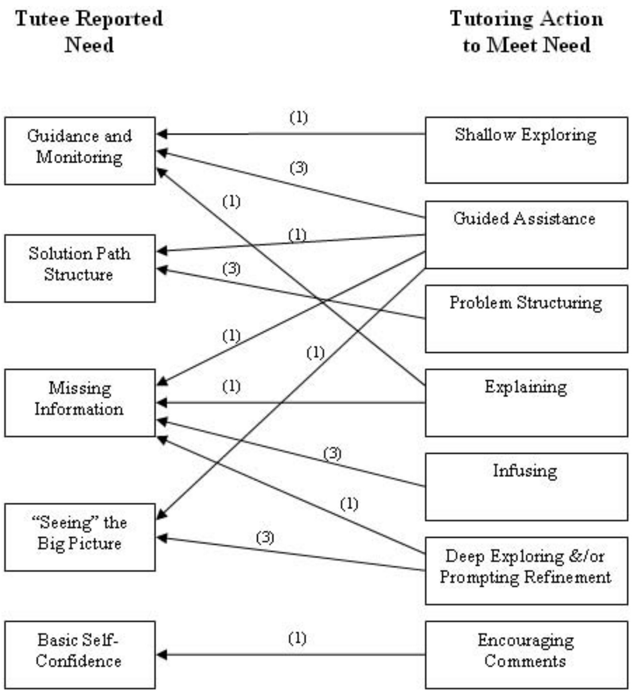

Fig. 3. Tutee reported learning needs mapped with tutoring actions to service those need.

ment serviced this need. The final quarter of the needs was simply to gain missing information. Infusing and explaining were the primary means to service this need.

How did rapport develop while tutoring?

Solid rapport appeared to develop in all six tutoring pairs. Casual observation revealed tutors and tutees actively engaged in dialogue and collaborative work. But what were the primary factors that caused rapport to grow?

Affirming comments are one means to develop rapport. All of the case data identify this type of interaction. Thirteen per cent of the weekly tutor and observer notes recorded tutor initiated rapport building comments (Table 1 above). These notes also recorded a small number of tutors reinforcing correct answers, which could similarly build rapport. The tutor improvement scripts also contained one planned response of affirming comments (Table 4). From the tutee perspective, supportive comments were identified in both the weekly surveys and the end-of-study questionnaire. Affirming statements have similarly been reported in naturalistic tutoring [11].

However, the tutees reported a very different view of rapport building in the end-of-study questionnaire. When asked, 'What actions did your tutor take to establish and build rapport with you?' the tutees identified five tutor actions:

1. Tutor was focused on the tutee's learning .... identified in 60% of the responses
2. Tutor worked at tutee's level .... identified in 50% of the responses
3. Tutor used the tutee's approach .... identified in 25% of the responses
4. Tutor engaged in casual conversation .... identified in 25% of the responses
5. Tutor made positive affirming statements .... identified in 15% of the responses

Strikingly, the tutees most frequently reported that rapport was built as the tutors focused on learning (item 1.). Coupled strongly with learning focus were actions at the tutee's level of understanding (item 2.). Learning focus at the tutee's level was further strengthened by using the tutee's approach (item 3.). This three-fold prescription of learning focus at the tutee's level while using the tutee's approach not only serviced learning, but also created rapport.

One tutee described rapport building this way (italics in parenthesis added), 'He wanted to break something into components of x and y *(learning focus)*. I suggested using tangential and normal components and he agreed to do it my way *(tutee's approach and level'* Three significant things happened in this one simple interaction. First, the tutor acknowledged the intelligence of the tutee by using the tutee's approach. Second, the tutor acknowledged the tutee's worth by letting the tutee's approach take precedence. Third, the tutee constructed knowledge starting from his pre-existing knowledge.

Another tutee wrote, 'He was very helpful, and still assumed that I knew what I was doing. He let me solve the problem in my own way *(tutee's approach and level)'*. This tutee makes a direct connection between being considered intelligent and using his own approach. Yet another tutee echoed a similar thought, 'He does do a good job of making me feel like an intelligent person instead of just doing the problem for me'.

This type of rapport building suggests important attributes of the model. Deep exploring by the tutor implicitly acknowledges the tutee's intelligence. The exploring also prepares the tutor to work at the tutee's level using the tutee's approach. Using the tutee's approach at the tutee's level is a simple way to engage the tutee within the tutee's representation. Thus, emphasizing deep exploring and working within the tutee's representation synergistically develop rapport.

In summary, rapport developed as the tutors gave affirming comments and focused on the tutee learning. A three-fold prescription of focusing on the tutee's learning while working at the tutee's level using the tutee's approach appeared to develop strong rapport. The actions of deep exploring coupled with working within the tutee's representation facilitate building rapport with this three-fold prescription.

CONCLUSIONS—A REVISED TUTORING MODEL

The data indicate that a revised model would more closely describe the reported effective practices. The revised model is diagrammed in Fig. 4.

1. The top of Fig. 4 emphasizes that the tutor's overarching goal is to focus all tutoring actions within the tutee's representation of knowledge. Tutoring actions within the tutee's representation help the tutee to correct and expand his or her pre-existing knowledge and construct new knowledge upon it. In this study, the large majority of reported effective actions showed evidence of the tutor working within the tutee's representation. Additionally, occasions where the tutor mixed the tutor's and tutee's representations significantly impeded learning. Since working from a tutee' point of view does not take specialized technical training, this idea can be implements by tutors at various levels of ability and education.
2. The centre oval in Fig. 4 emphasizes that tutor exploration of the tutee's deep (relational) knowledge by use of questions and prompts appears fundamental to tutoring within the tutee's representation of knowledge. Deep exploring can surface inadequate or incorrect tutee pre-existing knowledge, anchor learning firmly on the pre-existing knowledge and direct

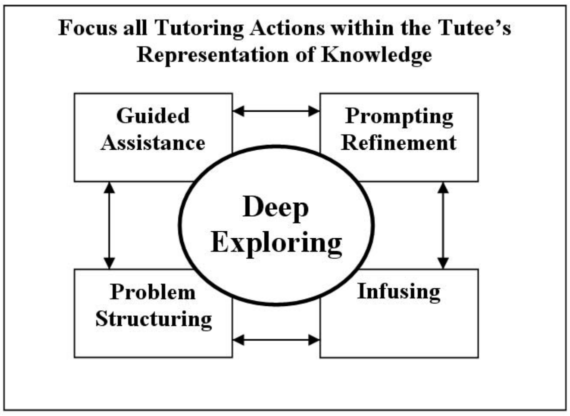

Fig. 4. A revised model of tutoring

subsequent tutoring actions. In this study the tutees reported that deep exploring mediated understanding of the 'bigger' picture. The observers noted several instances of deep exploring. The tutors reported that exploring was the most important skill to develop and the most useful tutoring action to employ. We suggest that exploring should begin each session and be used throughout.

3. The four boxes in Fig. 4 identify primary tutoring actions of prompting refinement, guided assistance, problem structuring and infusing. These four actions appear to meet the learning needs encountered in the tutoring sessions while focusing the tutor's actions within the tutee's representation.
   a. Prompting refinement, that is prompting a tutee to correct or refine inadequate or incorrect pre-existing knowledge, establishes a solid foundation on which to construct new knowledge. Prompting refinement coupled with deep exploring mediated the metacognitive learning reported by the tutees. One advantage of prompting refinement rather than direct correction is that the tutee does the knowledge construction and hence the tutoring is within the tutee's representation. As such, the prompt is more likely to actually mediate a change in the tutee's incorrect or inadequate pre-existing knowledge.
   b. Guided assistance, that is monitoring and providing assistance only as needed, serviced the broadest variety of learning needs. Guided assistance is a natural way to exercise the tutee's skills, work within the tutee's representation, and reduce problem complexity as necessary. Guided assistance was a large part of what the tutors did, was frequently reported as helpful by the tutees, and a significant portion of the tutor improvement plans. Guided assistance may be used as an ongoing learning context within tutoring sessions.
   c. Explicit problem structuring by the tutor provides the tutee with a structure within which to work. In cases where the tutee has low beginning knowledge, explicit problem structuring allows the tutee to construct new knowledge on his or her pre-existing knowledge, but in a new context. Though reported as helpful we conjecture that in some instances more learning may have been mediated if the tutor and tutee had jointly created the structure through the use of deep exploring and guided assistance.
   d. Infusing, that is providing targeted amounts of new knowledge only as the tutee can immediately use it, is a means to present new information in context with the tutee's representation of knowledge. By providing the information only as it can be immediately used, the information will more likely be presented within the tutee's representation and hence more frequently incorporated into the tutee's representation. We conjecture that infusing can be used to the exclusion of explanations from the tutor's representation.

In summary, strong rapport and effective learning appear to be created simultaneously when a tutor:

a. maintains a shared focus on learning with the tutee;
b. uses the tutee's approach to achieve the learning;
c. interacts at the tutee's level of understanding.

Furthermore, an emphasis on deep exploring and working within the tutee's representation appear to directly facilitate this three-fold prescription.

FUTURE STUDIES

In considering future studies, it is important to frame the current finding through the lens of qualitative research methods. The tutor, tutee and observer perspectives all indicated that the same tutor actions were being used. Furthermore, both the tutor and tutee perspectives identified the same set of actions as helping the tutee learn. Qualitatively combining these perspectives prescribed a revised model of tutoring. This model represents the findings within this specific case. This model may be transferable to similar cases, but is not necessarily generalizable. Further, this revised tutoring model reflects our initial tutoring model choices. Though we believe it is a sound foundation for tutoring, certainly other models are possible.

Two future studies suggest themselves. First, applying the revised model while tutoring a very different subject could identify both broader generalizations and/or specific embodiments of the model elements. Second, quantitatively measuring the model's effectiveness relative to unguided tutoring, or variations of the model, could validate the effectiveness of the model and/or its elements.

REFERENCES

1. B. S. Bloom, The 2 Sigma Problem: The Search for Methods of Group Instruction as Effective as One-to-one Tutoring, *Educ. Res.*, **13**, 1984, pp. 7–73.
2. P. A. Cohen, J. A. Kulik and C. L. C. Kulik, Educational Outcomes of Tutoring: A Meta-analysis of Findings, *American Educational Research Journal*, **19**, 1982, pp. 237–248.
3. B. R. Joyce, M. Weil and E. Calhoun, *Models of Teaching*, (7th ed.), Pearson Publishing, Boston, MA, (2004).
4. S. Adams, *A Guide to Creative Tutoring: The Tutor Ascendant,* Kogan Page, London, (1989).
5. E. Meyer and L. Z. Smith, *The Practical Tutor,* Oxford University Press, New York, (1987).
6. J. Rabow, T. Chin and N. Fahimian, *Tutoring Matters: Everything You Always Wanted to Know About How to Tutor,* Temple University Press, Philadelphia, (1999).
7. University of Idaho, Enriched Learning Environment Mentoring Community, Moscow, ID, 2006, http://www.webs1.uidaho.edu/ele/Mentors/index.htm
8. J. Bransford, A. Brown and R. Cockling, *How People Learn: Brain Mind, Experience and School*, National Academies Press, Washington, DC, (1999).
9. M. S. Donovan and J. D. Bransford, eds., *How Students Learn: Science in the Classroom,* National Academies Press, Washington, D.C., (2005).
10. J. W. Pellegrino, N. Chudowsky and R. Glaser, eds., *Knowing What Students Know: The Science and Design of Educational Assessment*, National Academies Press, Washington, DC, (2001).
11. A. C. Graesser, N. K. Person and J. P. Magliano, Collaborative Dialogue Patterns in Naturalistic One-to-One Tutoring, *Appl. Cogn. Psychol.*, **9**, 1995, pp. 495–522.
12. M. T. H. Chi, S. A. Siler, H. Jeong, T. Yamauchi and R. G. Hausmann, Learning from Human Tutoring, *Cogn. Sci.*, **25**(4), 2001, pp. 471–533.
13. M. T. H. Chi, S. A. Siler and H. Jeong, Can Tutors Monitor Students' Understanding Accurately?, *Cogn. Instr.*, **22**(3), 2004, pp. 363–387.
14. M. T. H. Chi, Constructing Self-Explanations and Scaffolded Explanations in Tutoring, *Appl. Cogn. Psychol.,* **10**(Special Issue), 1996, pp. S33–S49.
15. M. T. H. Chi, M. Bassok, M. Lewis, P. Reimann, P. and R. Glaser, Self-explanations: How Students Study and Use Examples in Learning to Solve Problems, *Cogn. Sci.*, **13**, 1989, pp. 145–182.
16. M. T. H. Chi, N. de Leeuw, M. H. Chiu and C. LaVancher, Eliciting Self-Explanations Improves Understanding, *Cogn. Sci.*, **18**, 1989, pp. 439–477.
17. P. L. Pirolli and M. Recker, Learning Strategies and Transfer in the Domain of Programming, *Cogn. Instr.*, **12**, 1994, pp. 235–275.
18. M. R. Lepper, M. Woolverton, D. L. Mumme and J. L. Gurtner, Motivational Techniques of Expert Human Tutors: Lessons for the Design of Computer-based Tutors, in *Computers as Cognitive Tools,* S. P. Lajoie and S. Derry (eds.), Lawrence Erlbaum, Hillsdale, NJ, (1991).
19. D. A. Schon, *The Reflective Practitioner*, Basic Books, New York, (1984).
20. D. A. Schon, *Educating the Reflective Practitioner*, Jossey-Bass, San Francisco, (1987).
21 R. E. Stake, *The Art of Case Study Research*, Sage Publications, Thousand Oaks, CA, (1995).
22. J. A. Leydens, B. M. Moskal and M. J. Pavelich, Qualitative Methods Used in the Assessment of Engineering Education, *J. Eng. Educ*, **93**(1), 2004, pp. 65–72.
23. R. J. Sternberg, *Cognitive Psychology,* (3rd ed.), Wadsworth/Thomson Learning, Belmont, CA, (2003).
24. J. W. Creswell, *Research Design: Qualitative, Quantitative, and Mixed Method Approaches*, (2nd ed.), Sage Publications, Thousand Oaks, CA (2003).

Steven C. Zemke, an Assistant Professor of Mechanical Engineering at Gonzaga University, teaches sophomore, junior and senior mechanical design classes. His research interests include creating enriched learning environments, interactions that mediate learning, team processes that mediate learning, teamwork processes and teaching methods for engineering. He was a design engineer for 23 years before teaching.

Donald F. Elger, a Professor of Mechanical Engineering at the University of Idaho in Moscow, has been actively involved with traditional research and pedagogy for the past 15 years. Research interests include the design of enriched learning environments, meaningful learning, mentoring, the design process, fluid dynamics and heat transfer. He teaches courses in design and in fluid mechanics.