Help! Active Student Learning and Error Remediation in an Online Calculus e-Help Community

Carla van de Sande and Gaea Leinhardt
University of Pittsburgh, USA
carlacvds@gmail.com

Abstract
Free, open, online homework help sites appear to be extremely popular and exist for many school subjects. Students can anonymously post problems at their convenience and receive responses from forum members. This mode of tutoring may be especially critical for school subjects such as calculus that are intrinsically challenging and have high attrition rates. However, educational research has focused on tutoring sessions that instruct students on a pre-determined set of material or topics, and there has been no systematic research on these dynamic, free, open, online tutoring communities. In order to distinguish the student-initiated e-help episodes from traditional tutoring sessions, we refer to them as "tutorettes."

Each tutorette was assigned a participation code that contained information on the number of contributions by each participant, the sequence of contributions, and the number of different participants. Student problem solving activity, defined by mathematical contributions and efforts, was measured for initial postings and for subsequent contributions. Finally, each tutorette was examined for evidence of mathematical errors and these were classified according to type: pre-calculus, operational, and conceptual. A tutorette on the limit concept is provided to demonstrate how mathematical queries are resolved in an SOH e-help community.

Participation and problem solving attempts provided evidence of active student learning. Instead of simply using the tutors to do their homework, many students made initial attempts at solutions, queried tutor responses, and applied the help they received to make progress on solving problems. This behaviour appeared to be influenced by the actions of the tutor: Providing solution sketches accompanied by asking direct questions encouraged dialogue, whereas providing quasi-complete worked solutions seemed to have the opposite effect.

In contrast to classroom instruction, students in this e-help community appeared comfortable in presenting incorrect work and tutors were open and forthright in their commentaries, evaluations, and explanations. In addition, tutors modulated their responses according to the type of error. Pre-calculus errors and operational (calculus) errors were not accorded the same depth of explanation as conceptual misunderstandings.

Keywords: tutoring, e-help communities, discussion forums, calculus tutoring

1. Introduction

Help-seeking is recognized as an effective means for students to cope with academic challenges (Nelson-Le Gall, 1985), and student-initiated tutoring, in which a student seeks a tutor for help (usually for a specific problem), is a common manifestation of this phenomenon. This type of tutoring traditionally occurs in face-to-face settings, such as in university-sponsored help centres. However, since computer networking has become ubiquitous, a new context for tutoring has emerged in which students and tutors are not necessarily linked by physical proximity. The "net generation" (Oblinger and Oblinger, 2005) and "digital natives" (Prensky, 2001) are using the Internet to voice their requests for help. Students are participating in topic-specific, free, open, asynchronous Web-based forums for help with homework problems and answers to questions. These e-help communities may be the only recourse some students have for receiving help outside of the classroom on homework assignments or on studying for examinations. In particular, this opportunity is critical for some students taking introductory calculus, a course that is renowned for its challenging nature and high attrition rate. A casual survey of the Internet posting subjects for mathematical discussion forums that include subjects such as geometry, trigonometry, and standardized test preparation reveals that calculus is one of the most frequented subject areas, with multiple postings daily. However, despite the existence and apparent functionality of several mathematical help forums for today's students, there has been no systematic study of student-initiated tutoring in Web-based forums.

In order to distinguish the tutoring exchanges that we study from the "tutoring" that has been the subject of previous educational research, we use the term "tutorettes" for student-initiated episodes that are typically brief and involve a specific problem situation. In contrast, the "tutoring'' that has been the subject of previous educational research resembles scaled-down classroom instruction in that the tutor is assigned the task of covering a pre-determined topic or set of topics (see Cohen, Kulik and Kulik, 1982 for a meta-analysis of 65 studies). In opening up this new area of research, many questions can be posed and answered: What are the effects of different participation structures (van de Sande and Leinhardt, 2007)? What are recurring

Reference this paper as:
van de Sande, C. and Leinhardt, G. "Help! Active Student Learning and Error Remediation in an Online Calculus e-Help Community." *The Electronic Journal of e-Learning* Volume 5 Issue 3, pp 227-238, available online at www.ejel.org

patterns of questions around a given topic? What are the similarities and differences between face-to-face help center encounters and online tutoring in the same content (van de Sande in preparation)? The research reported here examines the extent to which Web-based tutorettes reflect active student learning and error remediation, two elements of effective instruction according to educational research. A tutorette on the mathematical concept of the limit is presented as an example of how a challenging topic is discussed and resolved in a tutoring e-help community.

1.1 Active student learning

In order to learn, an individual must become actively engaged with the material, ideas, and uses of concepts and procedures to be learned. However, there are a variety of ways in which a learner can be active. Most reform-based educators urge a particular kind of active learning, for instance, that instruction should position students as active participants in the construction of knowledge rather than as passive recipients of information (Greeno, 2003; Lave and Wenger, 1991; Rogoff, 1990). This position calls for both a definition of "active" participation and methods of assessment. According to Scardamalia and Bereiter, (1991), active student learners are those that select problems, ask questions, and self-monitor their understanding. Although there is ample evidence to suggest that productive student engagement and participation fosters learning, active student learning is not a feature of typical classroom instruction. One explanation for its absence involves pragmatics: Coordinating a large number of students learning simultaneously might interfere with active student participation on an individual basis. However, active student engagement, as measured by the initiation of exchanges and questioning behavior, was also not supported in face-to-face, one-on-one tutoring sessions (Graesser, Person and Magliano, 1995). Although student questions were more frequent in these tutoring contexts than in classroom settings (Graesser and Person, 1994), the majority of questions were asked by tutors and students rarely initiated exchanges.

Active student learning, then, does not appear to be a phenomenon that naturally occurs in face-to-face instructional settings. Are other instructional settings more amenable to active student learning? By definition, online homework help forums are likely locations for active student participation since it is the role of students exclusively in these forums to initiate questions and seek resolution. In addition, the asynchronous and anonymous nature of such exchanges would seem to encourage student participation. Students are not constrained by the pace of instruction, can pose questions as they arise, and are able to present ideas in an environment where face-saving is not an issue. However, there is the possibility that students participating in web-based tutorettes are "executive'' (or dependency-oriented) versus "instrumental" (or mastery-oriented) help-seekers (Nelson-Le Gall, 1981). That is, these students may appear to be active learners but may simply be seeking worked solutions to homework problems rather than seeking help on understanding the relevant procedure or underlying concept. In our corpus of online calculus exchanges, we distinguish between these types of help-seeking by looking for evidence of active student learning in terms of student participation within tutorettes and in terms of student problem-solving contributions.

1.2 Errors and error remediation

Errors are mistakes: Some errors are trivial and some represent a quite profound misunderstanding of the situation. When students produce errors in the process of engaging with mathematics, it can be a moment of learning if the error sets up an occasion of serious exchange and consideration of the ideas involved in making the mistake. Therefore, it is precisely in these situations that the response of a tutor is critical. Following an error, a tutor may provide information about the existence, the nature, or the consequences of the error, and may do so in an explicit manner or less directly by hinting. Analyzing the timing and informational content of feedback (McKendree, 1990), the manner in which it is presented (Lepper et al, 1990), and the underlying situational features that prompt different tutor responses (Hume et al, 1996), has been instrumental in understanding the effectiveness of (human) tutoring and in shaping the design of computer-based tutoring systems (Merrill et al, 1992). One key finding is that tutors appear to modulate their responses based on the perceived criticality of an error: Errors that are judged to be less consequential for learning are treated in a different manner than errors that are considered to involve focal goals or objects in the domain (Littman, Pinto and Solway, 1990; Merrill, Reiser and Landes, 1992).

Do tutors modulate their responses to student errors in online e-help communities? Although they are instructional by nature, tutorettes are quite different from the traditional tutor sessions that have been used for the evaluation of feedback. For instance, the tutors are not constructing "tutoring plans" that will support extended instruction with the student. Instead, their goal is to quickly and efficiently answer a given student query before moving on to the next. At the same time, the tutors in e-help communities are in a position to make some assessment of a student's knowledge state by the work that is posted, the way a question is framed, and the response to their actions. As a first step for investigating errors and error remediation in calculus tutorettes, we have constructed a system for classifying the mathematical errors in our corpus and have explored the corresponding patterns of remediation.

2. Methods

2.1 The corpus

As part of our ongoing research, we have collected and analyzed tutorettes from free, open, online help sites that represent different participation structures, span international borders, and pertain to various mathematical topics. We have identified two basic participation structures: Spontaneous Online Help (SOH) sites permit any forum member to respond to postings, whereas Assigned Online Help (AOH) sites assign postings to vetted volunteer tutors. The corpus used in this study (Cohort 1) contained 100 sequential introductory calculus SOH tutorettes that were collected from www.mathgoodies.com. `MathGoodies.com` is representative of other math homework SOH sites and includes an active pre-calculus and calculus homework help forum. The Advanced Placement Calculus course description (College Entrance Examination Board, 2003) was used to delineate "introductory" (versus pre-calculus or advanced) calculus tutorettes that were included in the analysis. The Math Goodies homework help forums are part of an online resource founded in 1998 and maintained by former secondary mathematics and computer science instructor, Gisele Glosser. Although this is an SOH site, there are assigned moderators for each individual forum who can edit, delete, or prune posts. Other participants are categorized as New Members, Average Members, Senior Members, or Advanced Members depending on their number of postings, either giving or seeking help. The explicit rules for participation in the forum include a mandate not to request help on take-home exam questions, a request to search the forum prior to posting a question, and admonitions to specify the entire question (including instructions), to show one's work on the problem, and to use the provided mathematical symbol keys to facilitate communication.

2.2 Coding

Problem-solving activity was measured by student participation within a given tutorette and by contributions to the problem-solving activity. Each posting was assigned a "participation code" that differentiated the participants of that posting and characterized the sequence of activity. A "1" was used for the initiator of the posting, "2" was used for the next participant, and so on. For example, a participation code of 1231 would be a posting by three forum members in which a student (1) requested help, participants (2) and (3) responded, followed by a final contribution from the student (1). The length of a code, then, signifies the number of exchanges in the tutorette, the ordering of numbers within a code tracks the sequence of participation, and the largest number in the code reflects the number of different participants in the exchange. In addition, each tutorette was examined to see if the student demonstrated problem-solving activity in the initial posting and whether there was subsequent activity as the tutorette was enacted. There were four possible classifications, representing all possible initial/subsequent problem-solving activity configurations. In order to distinguish between executive and instrumental help-seeking, the classification was conservative; thus, to qualify as a problem-solving attempt, the effort had to extend beyond listing possible strategies or questioning a tutor to include an explicit proposal of solution steps. Two coders independently classified problem-solving activity with high inter-rater reliability (κ = .93, n=20), and all disagreement was resolved through discussion.

In order to investigate errors and error remediation, the content of each of tutorette was coded for mathematical accuracy. Errors were defined as statements that were logically inconsistent or demonstrated a misunderstanding regarding some aspect of mathematics as opposed to those that indicated a lack of knowledge. The errors were then classified according to type: pre-calculus, operational, and conceptual. Pre-calculus errors involved arithmetic miscalculations (such as incorrect summands) or violations of algebraic principles (such as the distributive law). Operational errors involved the incorrect implementation of an algorithm or procedure of calculus (such as the chain rule). Conceptual errors, as the name suggests, involved the misunderstanding of a calculus concept (such as the limit). A posting could contain errors of more than one type, and each error was classified separately.

3. Results

3.1 Active student learning

In order to detect active student learning, we first examined the participant codes (Figure 1) for the presence of student participation beyond initiating the posting. One broad indication of student activity is the likelihood of a student re-entering a discussion; active learners would be more likely to make contributions and to extend exchanges. Although for many of the tutorettes there is no record of whether or not the student profited from the help or engaged in any further activity on the particular problem, the student who initiated the dialogue made at least one further contribution in 46 instances and made two or more additional contributions in 17 instances. These numbers indicate that many students are engaging in discussions in this e-community. However, this analysis, on its own, does not reveal the nature of their contributions and whether the participation is indicative of executive or instrumental help-seeking.

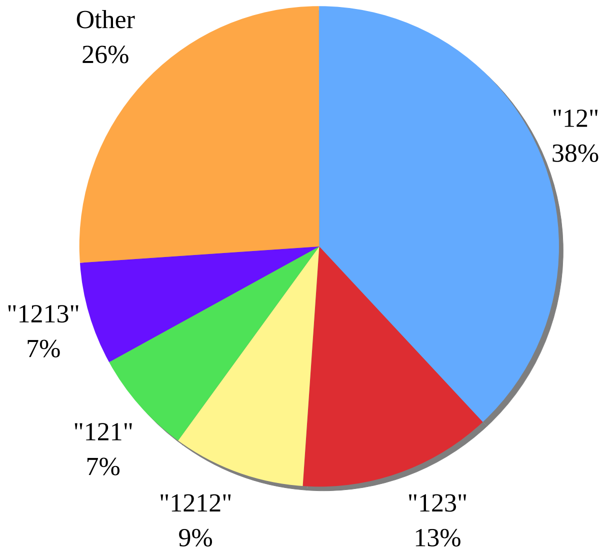


Figure 1: Percentages of participant codes. “Other” category includes two unanswered postings and other less common participant codes. A closer examination of initial and subsequent problem-solving efforts by the student-initiators provides a more refined measure of student activity and helps discern between executive and instrumental help-seeking. Figure 2 shows the percentage of tutorettes that display initial and subsequent attempts by the student-initiator at solving the problem.

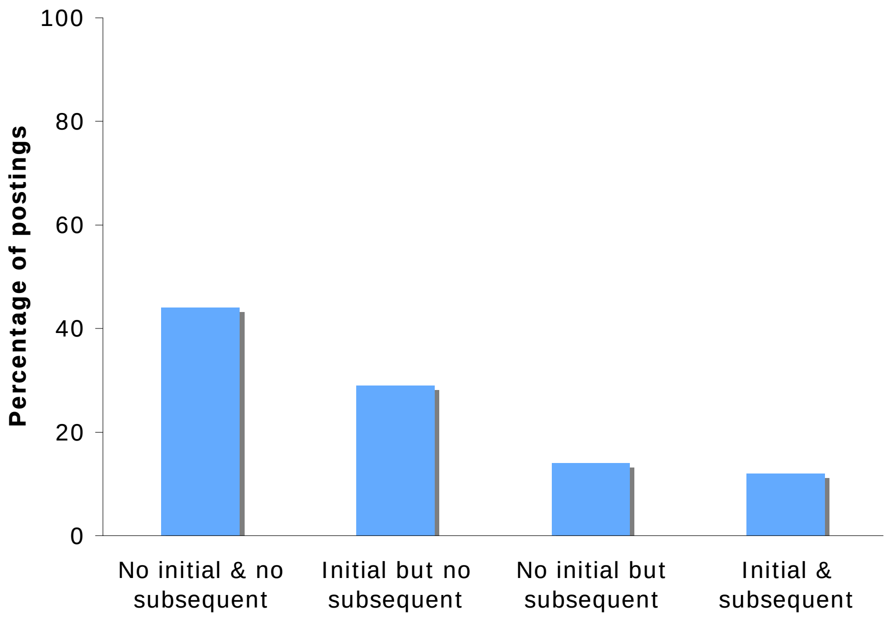


Figure 2: Student-initiator problem-solving activity[1].

Twelve percent of the tutorettes reflect problem-solving activity both initially and subsequently, 14% reflect an increase in problem-solving activity, 29% reflect problem-solving activity by the student in the initial posting only, and 44% reflect no problem-solving activity by the student-initiator. These latter categories are potential indicators of web-based SOH sites enabling executive help-seeking and were examined more closely to determine tutor actions that may have contributed to the lack of student problem-solving activity. If, for example, tutors provide complete worked solutions, then there is less incentive for students to engage in problem solving.

The tutorettes in which the student-initiator did not participate in any problem-solving activity beyond perhaps an initial attempt revealed several characteristics of tutor activity that may contribute to a low level of student problem-solving activity. In the majority of these tutorettes, the student received a complete worked solution (n=23 for no initial student attempt, n=10 for initial student attempt) or a partial solution or solution outline (n=13 for no initial student attempt, n=10 for initial student attempt). The level of detail in the solution sketches varied greatly, but there were several instances in which the challenging part of the problem was provided for the student with only a few remaining algebraic steps left for the student to complete. In some cases, one tutor responded to a student with a solution sketch, and, without any further contributions from the student, another tutor volunteered a full worked solution, potentially deterring the student from attempting to apply the sketched solution steps. Thus, the "spontaneous" characteristic of this web-based forum[2], although potentially a mechanism for catching mistakes and introducing multiple perspectives, is sometimes redolent of "too many cooks in the kitchen."

Alternatively, the examination of tutor actions in tutorettes that resulted in an *increase* in student activity may reveal ways of supporting and encouraging student problem-solving attempts. Although the number of such tutorettes was small in this corpus, some tutorial moves did appear to support instrumental help-seeking. For instance, the inclusion of partial solutions or solution sketches followed by a direct question, such as ``What do you need to integrate to find the arc-length?'', provided limited information and directly prompted students to work further on the problem. Hinting, in this fashion, is a common tactic used in traditional tutoring sessions that functions as a prompt for students to access information already known and to carry out the next solution step (Hume et al, 1993).

3.2 Errors and error remediation

Because previous research has shown that tutors, as well as students, make mathematical errors in Web-based and face-to-face tutorettes (van de Sande and Leinhardt, 2007; van de Sande, in preparation), we examined the contributions of participants in both roles. The error rate for tutor contributions was impressively low for this corpus. Only three tutorettes contained mathematical errors made by tutors. Two of these were sign errors (one involving the computation of a derivative and the other the factorization of a quadratic) and the third concerned a trigonometric identity. In contrast to other SOH corpora that we have analyzed, none of these errors was discovered or addressed by another forum participant. In general, SOH communities are wikipedia-like and members share responsibility with one another by catching mistakes and publishing corrections. However, the fact that two of these tutor errors were relatively minor may have contributed to their slipping by unnoticed by others. One sign error result was a value to be squared so that its sign was, in some sense, irrelevant; the other sign error occurred in an explanation of a removable discontinuity and did not affect the ultimate conclusion. The remaining error occurred when a tutor utilized a trigonometric identity that is not generally well known and, therefore, may not have been detected by fellow participants.

In contrast, the error rate for student contributions was relatively high. Of the 55 tutorettes in which the student displayed problem-solving activity, 34 contained errors. This finding attests to the function of open, online, help forums as safe environments for students to present their work and tutors to critique this work, as well as to the social norms of this particular e-help community. Students did not appear to be concerned with "saving face" and tutors did not appear to be constrained by universal conversational maxims and politeness principles that, in face-to-face encounters, may conflict with pedagogical goals (Person et al, 1995). Also, the "rules for participation" for the `mathgoodies.com` community specified that students were

[1] One posting was a request for a reference and was therefore excluded from this analysis.

[2] The "spontaneous" characteristic of this help site is reflected by the number of tutorettes (39) in the corpus in which more than one tutor participated, either addressing the student or another tutor.

responsible for showing all work, and students who routinely did not show work were sometimes chastised and denied help. This practice encourages students to publish their misunderstandings and incorrect results, thereby contributing to the magnitude of the error rate.

Table 1: Type and number of student errors with example of each.

Type	Number	Example
Pre-calculus	8	-sin t – (sint t + t cost) = -2sin t + tcos t
Operational	15	Use of the harmonic series, 1/n, to investigate the convergence of the series n/(n+1)$2^{(n-1)}$
Conceptual	14	f(x) = x^6 – 3e^x cos(x) + e^3.5 f'(x) = 6x^5 -3xe^(x-1)cosx + 3e^xsinx + 3.5e^2.5

Table 1 shows the number of student errors in this corpus according to type and an example of each. The majority of the errors that students made were calculus-based, either involving the implementation of an algorithm (15) or the misunderstanding of a concept (14). Only 8 errors pertained to arithmetic or algebraic operations. Of these, 2 were arithmetic errors, 4 were errors concerning the distributive property, and 2 resulted from incorrect calculations of a function value. The typical response of the tutors to this type of error was to draw attention to the mistake (directly or using hints), with minimal explanation of the violated principle. For instance, when a student was performing differentiation and, in the process, neglected to distribute the negative sign to both terms of an expression, a tutor responded by pointing to the line that contained the error and identifying the incorrect term in the expression using red-colored font: "–sint – (sint + tcost) = -2sin t + tcos t **< -- here is your mistake … check the sign of tcost**."

Despite the difference in the mathematical domain (calculus vs. pre-calculus), the errors that students made in operationalizing a concept met with much the same response: The error was corrected with little explanation of the underlying principle. For example, when a student was investigating the convergence of an infinite series using the limit comparison test and chose an unproductive comparison series, a tutor responded by providing an appropriate comparison series and solution but with no explanation regarding the student's failed attempt. This mode of response to operational errors in tutorettes is in keeping with research on traditional tutoring in that tutors generally do not perform detailed evaluations of students' knowledge (Putnam, 1987) or make inferences about specific student "bugs" (McArthur, Stasz and Zmuidzinas, 1990). Presumably, the errors that we classified as operational matched with those that the tutors judged to be less consequential for learning and were therefore treated somewhat cursorily.

The third type of error centred on conceptual misunderstandings or interpretations. Tutors responded to this type of error in a very different way from the way they responded to the other two error types and they generally provided explanations that invoked mathematical definitions and principles. For example, when a student overgeneralised the rule for differentiating powers to exponential functions, the tutoring included responses such as: "The derivative of an exponential term is the exponential term times the derivative of the exponent" and "Remember, the derivative of a constant is 0, therefore, $e^{3.5}$dx is 0." Responses of this nature prompted students to reformulate their understanding of the concept. In this example, the student queried, "Oh, the derivative of -3e^x is itself?" and a tutor replied with a proof of this fact using the product rule on the terms -3 and e^x.

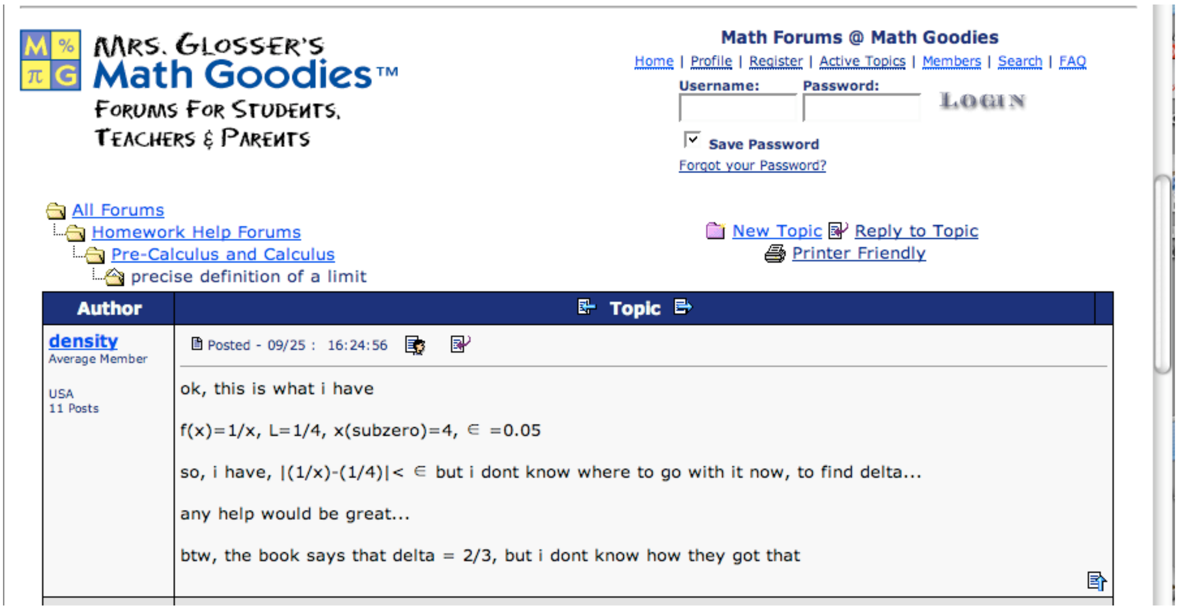
We hypothesize that many errors of this latter type may result from an unproductive perspective on the problem situation, specifically one that does not afford reasonable opportunities for solution (see Greeno and van de Sande, 2007 for a discussion of perspectival theory). Adopting a visual analogy, problem solvers reach an impasse when there are some (mathematical) objects that are not placed in the foreground or background in a helpful manner. In some cases, an unproductive perspective may be the result of trying to operate according to a schema that is too specific and therefore not applicable. This difficulty results from the tendency of students to latch onto simple examples that a mathematics instructor uses to introduce a new topic. Students then construct a schema for solving problems that is limited to these example types: "[It is] almost impossible to give students simple experiences without giving them correspondingly simple long-term conceptions of the concepts being introduced" (Davis and Vinner, 1986). Constructing an alternative perspectival understanding is an effortful process, but one that has implications for conceptual growth (Greeno and van de Sande, 2007). In the next section, we present an example of a tutorette that illustrates how an alternative perspective was introduced and adopted by a student.

4. A tutorette on the limit

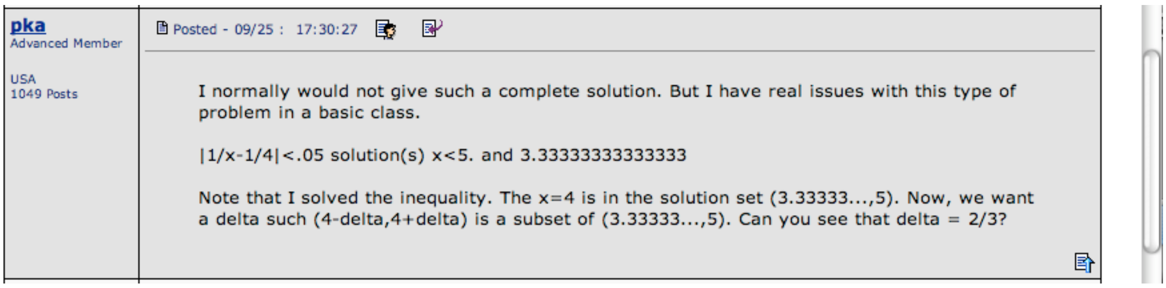
The following example illustrates how an SOH site can function as a collaborative tutoring effort to effectively help students understand a challenging calculus concept, namely the limit. The exchange is an example of instrumental help-seeking in which two tutors (**pka** and **tkhunny**) responded with alternative perspectives. The student (**density**) questioned the first tutor's solution. Because the first tutor was unsuccessful at framing an explanation for the student, s/he requested an additional tutoring help. Another tutor entered the dialogue and provides the sketch of a solution from an alternative perspective. (The participant code for this dialogue between the student and the two tutors is 1212131.) This second perspective was successfully understood by the student, and the situation was resolved.

The formal mathematical definition of the limit, in particular, is often a source of extreme difficulty for students (Tall, 1993), although its presentation, at least to some extent, is not unusual in an introductory calculus course. Typical problems include the application of the formal definition of the limit to a given function. Instruction usually begins with linear functions and then progresses to more complex cases, such as reciprocals (e.g., f(x) = 1/x). The application of the formal definition to a linear function can be performed using a sequence of algebraic manipulations (factoring followed by division) but this 'procedure' does not extend to more complex functions without significant modifications. This situation presents a difficulty for students who have acquired a schema for applying the formal definition but have not grasped the underlying limit concept.

In the initial posting, **density** posed the problem and an attempt (albeit weak) at starting a solution. As is often the case with homework assignment from a textbook, **density** knew the final answer but could not construct the accompanying solution steps:



A short time later, a tutor (**pka**) responded with a partial solution, preceded by a comment on the nature of such problems for introductory calculus:



Despite the characterization ("I normally would not give such a complete solution."), **pka** did not provide a complete worked solution but rather provided select solution steps and ended the posting with a question, "Can you see that delta = 2/3?" This move encouraged active learning since **density** was prompted to use this additional information to work through the problem. **Density** responded by questioning how **pka**'s solution supported the answer and presented his/her work on the problem. This work corresponded to the enactment of a schema for applying the formal definition of the limit to a linear function and resulted in an acknowledged impasse. **Density** was trying to manipulate the absolute value expression to resemble the desired algebraic form which would have |x-4| on one side of the inequality and a constant multiple of $\in$ on the other:

> **density**
> Average Member
> USA
> 11 Posts
>
> Posted - 09/25 : 20:15:34
>
> how did you get delta = 2/3?
>
> this is what I did,
>
> |(4/4)(1/x) - (x/x)(1/4)| < ∈
> |(4/4x) - (x/4x)| < ∈
> |(4-x)/(4x)| < ∈
> |(1/4x)**x**(-1)(x-4)| < ∈
> and then im left with |1/4x|**x**|x-4|< ∈
> but now how do i isolate that |x-4| so that i can find epsilon ?

Pka, however, was apparently unable to explain the solution and called for help from other forum participants. This is evidence that, just as students seem comfortable voicing questions and producing imperfect work in this e-help community, tutors also appear comfortable publicly acknowledging difficulties:

> **pka**
> Advanced Member
> USA
> 1049 Posts
>
> Posted - 09/25 : 20:53:16
>
> Can someone else help?
> It seems so clear to me!
> I do not know what else to say.

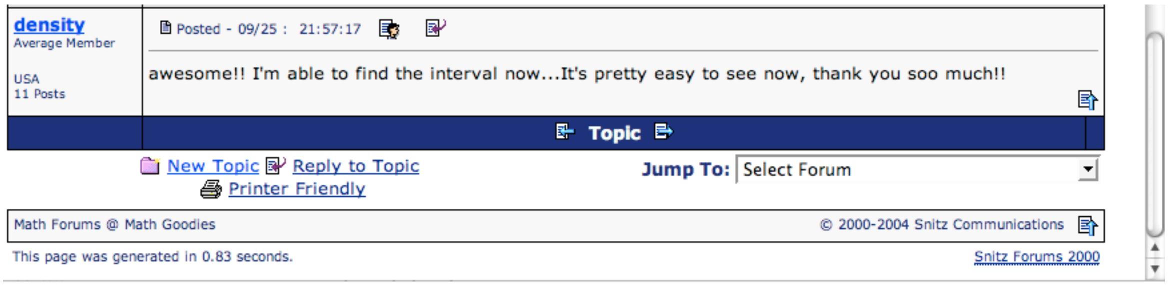
Density responded apologetically and clarified his/her state of understanding. **Density** understood how **pka** could arrive at the final answer if an earlier claim was accepted (**pka**: "Note that I solved the inequality") but did not understand the justification for this claim, especially in light of the impasse that **density** had reached:

> **density**
> Average Member
> USA
> 11 Posts
>
> Posted - 09/25 : 20:59:07
>
> Sorry, I guess im just blind on this one...
> I don't see how you came up with the interval 3.3333 < x <5
> but I do understand that if the interval is (3.33333,5) than delta is 2/3, or .6666666666667 , that's easy to see

It is at this point that another tutor, **tkhunny**, entered the dialogue and presented an alternative perspective that focused on the *dynamic* nature of limits; the value of the limit of a function at a point (if it exists) is the value that the function is arbitrarily close to as the independent variable *approaches* that point. Thus, **tkhunny** suggested considering the behavior of the function for values LESS than 4 and values GREATER than 4. The absolute value – the source of **density**'s impasse – was then equivalent to a simple inequality for each case:

> **tkhunny**
> Advanced Member
> USA
> 501 Posts
>
> Posted - 09/25 : 21:40:36
>
> Let's just hang around x = 4, close enough to avoid zero (0).
>
> If we are LESS than x = 4, approaching from the low side, so that 1/x > 1/4
> (or [(1/x)-(1/4)] is positive), we have:
> |(1/x)-(1/4)| = [(1/x)-(1/4)] < 0.05
>
> That should be easy enough to solve, recalling that it is valid ONLY for x < 4.
>
> If we are GREATER than x = 4, approaching from the high side, so that 1/x < 1/4
> (or [(1/x)-(1/4)] is negative), we have:
> |(1/x)-(1/4)| = [(1/4)-(1/x)] < 0.05
>
> That should be easy enough to solve, recalling that it is valid ONLY for x > 4.
>
> Edited by - David on 08/26/2007 12:58:31

Although **tkhunny** did not provide a complete worked solution (leaving the solution of the inequalities to **density**), this sketch was sufficient for **density** to adopt the alternative perspective and thereby to understand the derivation of the interval in question. **Density** replied with gratitude and enthusiasm, demonstrating clearly the effectiveness of the help received:



Despite the apparent success of this tutorette, however, its outcome is not without concern. Although **density** was able to solve the problem by adopting the perspective of **tkhunny**, there is no indication that **density** made progress toward reconciling the original schema-based approach and this alternative perspective. In other words, it is most probable that, following the exchange, **density** retained two disconnected perspectives on the formal definition of the limit: a schema-based approach for linear functions and a dynamic approach for more complex functions, such as reciprocals. The relationship between these two was not constructed in the tutorette. This example calls attention to the importance of carefully examining the ways in which tutors specifically address and build upon student activity, especially in light of constructing an understanding of the student's perspective. Instruction as a collaborative activity requires that tutors take student perspectives into account rather than simply presenting alternatives.

5. In Conclusion

Students are turning to discussion forums in order to receive help on mathematics homework assignments and studying for examinations. These sites are a resource that allows students to complete homework assignments and learn outside of classroom instruction and may be critical for the success of some students, especially in introductory calculus courses. Because participants are anonymous, these communities provide a relatively safe environment for asking questions, presenting solutions, and critiquing work. In addition, several of these homework help forums have the added benefit of being free of cost. While some of these forums provide tutoring from assigned volunteer tutors (usually mathematicians or upper-level mathematics students) who meet certain criteria (AOH sites), there are also several forums that provide spontaneous help by other members of the e-community (SOH sites). The research reported here investigated a corpus of 100 sequential tutorettes on introductory calculus topics from one such SOH site that is taken as representative of other web-based homework help forums of this type. The analyses focused on active student learning and error remediation, two elements of effective instruction.

Active student learning involves problem selection, questioning, and self-regulation and is a desirable element of instruction that is not often achieved in traditional classroom situations or in traditional face-to-face tutoring (Graesser, Person and Magliano, 1995). However, there was evidence of active student learning in the SOH tutorettes. If students in this community were solely "executive" or dependency-oriented help-seekers, then the participation codes would have been limited to instances of "12", that is, postings in which a tutor responds to a student query. This was not the case. Instead of simply using the tutors to do their homework for them, many students took part in these dialogues as "instrumental" or mastery-oriented help-seekers; students made initial attempts at solutions, queried tutor responses, and applied the help they received from tutors to make progress on solving problems. Furthermore, this behavior was influenced, at least to some extent, by the actions of the tutor. Some tutor actions seemed to encourage active student problem-solving, whereas others may have discouraged it. In particular, providing solution sketches (versus complete worked solutions) accompanied by asking direct questions encouraged dialogue; providing complete (or close to complete) worked solutions seemed to have the opposite effect.

Related to the issue of active student learning in instruction is the issue of how errors are handled. One mark of a learning community is that ideas can be questioned, elaborated, challenged, and revised safely. In practice, this has proven problematic for face-to-face instructional settings, where students tend to refrain from asking questions and presenting work that displays knowledge deficiencies and tutors are sometimes reluctant to criticize student contributions. In the SOH e-help community, however, students appeared comfortable in presenting incorrect work and tutors were open and forthright in their commentaries, evaluations, and explanations and vice-versa (van de Sande, in preparation). Saving face was clearly not the central concern, although members still adhered to a standard of politeness: Criticism was directed at the incorrect mathematical information rather than at contributors. In addition, e-help tutors in the SOH community modulated their responses according to the type of error. Pre-calculus errors and operational (calculus) errors were not accorded the same depth of explanation as conceptual misunderstandings.

The e-help community that we chose for this project was characterized as *spontaneous* online help. That is, any forum member could take on the role of tutor, regardless of mathematical expertise or instructional experience. This participation structure fostered collaboration between individuals with different abilities, specialties, and interests. In this corpus, the collaborative potential of an SOH site was evident in the participation by multiple tutors per posting; as many as 4 different tutors took part in a single tutorette. The spontaneous (SOH) feature of the discussion forum also encouraged and supported the contribution of alternative perspectives on problems. We concluded that this “party-line” characteristic of SOH sites has the potential of helping both students and tutors understand problems in a multitude of ways (many of which may be novel). However, as the tutorette on the formal definition of the limit demonstrates, the benefits may be curtailed if tutors do not connect their responses to a student’s perspective and help reconcile alternatives.

The larger aim of this project aims to define and evaluate effective learning in the context of Web-based tutorettes. As a starting point, we have begun investigating features of ideal instruction that stem from cognitive research and that have been applied to traditional face-to-face tutoring corpora. Clearly, this is not an ideal fit since the goals, setting, and composition of the instruction are vastly different. On the other hand, at the core, tutorettes are instances of instruction and learning, and, as such, share many of the same ideals. Understanding how these ideals (and potentially others) are realized in e-help communities is important for a number of reasons. First of all, these communities are flourishing as instructional support for today’s students. Given that these communities may become the new norm for seeking help on homework, it is important to understand how they function and how they impact students’ understanding. Do tutorettes help students beyond the construction of a solution for the problem that is posted? A second reason for pursuing this research involves the variety of forum types available -- gratis versus subscription and AOH versus SOH. Do these communities manifest different elements of ideal instruction, and, if so, which ones and why? For instance, it may be the case that SOH sites are more likely to introduce students to multiple perspectives on a given problem, whereas AOH sites tend to encourage more in-depth explanations. Knowing how the different e-based communities function could inform the formation or endorsement of such a community. Finally, this research has implications for the design of intelligent tutoring systems, particularly those that contain a dialogue component such as an automated pedagogical agent. These systems reside in computer environments and, as such, have much in common with Web-based homework help sites. Identifying the ways tutors communicate with students in e-communities can inform the construction of more realistic and effective computerized pedagogical agents. In general, the message is clear: Students of today are voicing their appeals for help in web-based homework help forums. As educational researchers, what, then, is our response?

Acknowledgements

This project was partially supported by a grant from the William and Flora Hewlett Foundation. We would like to thank Dr. Arthur Graesser for discussing this work in light of his expertise in tutoring, the members of the ongoing Interaction Analysis seminar chaired by James G. Greeno at LRDC for discussion of early forms of these ideas, and Joyce Fienberg for reviewing and editing the manuscript. Naturally any flaws or errors in this paper are our own and not those of the parties mentioned above.

References

Cohen, P. A., Kulik, J. A. and Kulik, C.-L. (1982) “Educational outcomes of tutoring: A meta-analysis of findings”, *American Educational Research Journal*, vol. 19, pp. 237-248.

College Entrance Examination Board (2003) “2004, 2005 course description for AP calculus AB and BC”, pp. 12-16, New York: Author.

Davis, R. and Vinner, S. (1986) “The notion of limit: Some seemingly unavoidable misconception stages”, *Journal of Mathematical Behavior,* vol. 5*,* pp. 281-303.

Graesser, A. C. and Person, N. K. (1994) “Question asking during tutoring”, *American Educational Research Journal*, vol. 31, pp. 104-137.

Graesser, A. C., Person, N. K. and Magliano, J. P. (1995) “Collaborative dialogue patterns in naturalistic one-to-one tutoring”, *Applied Cognitive Psychology*, vol. 9, pp. 495-522.

Greeno, J. G. (2003, November) “A situative perspective on cognition and learning in interaction”. Position paper presented at a workshop, *Theorizing learning practices*. University of Illinois, Urbana-Champagne.

Greeno, J. G. and van de Sande, C. (2007) “Perspectival understanding of conceptions and conceptual growth in interaction”, *Educational Psychologist*. vol. 42, No. 1, pp. 9-23.

Hume, G., Michael, J., Rovick, A. and Evens, M. (1996) “Hints as a tactic in one-on-one tutoring”, *The Journal of the Learning Sciences*, vol. 5, pp. 23-47.

Lave, J. and Wenger, E. (1991) *Situated learning: Legitimate peripheral participation.* Cambridge, UK: Cambridge University Press.

Lepper, M. R., Aspinwall, L., Mumme, D. and Chabay, R. W. (1990) “Self-perception and social perception processes in tutoring: Subtle social control strategies of expert tutors”, in J. M. Olson & M. P. Zanna (eds.) *Self inference processes: The sixth Ontario symposium in social psychology*, Lawrence Erlbaum Associates, Inc., pp. 217-237.

Littman, D., Pinto, J. and Solway, E. (1990) “The knowledge required for tutorial planning: An empirial analysis”, *Interactive Learning Environments,* vol. 1, pp. 124-151.

McArthur, D., Stasz, C. and Zmuidzinas, M. (1990) “Tutoring techniques in algebra”, *Cognition and Instruction*, vol. 7, pp. 197-244.

McKendree, J. (1990). “Effective feedback content for tutoring complex skills. *Human-Computer Interaction,* vol. 5, pp. 381-413.

Merrill, D. C., Reiser, B. J. and Landes, S. (1992, April). “Human tutoring: Pedagogical strategies and learning outcomes”, *paper presented at the annual meeting of the American Educational Research Association,* San Francisco.

Merrill, D. C., Reiser, B. J., Ranney, M. and Trafton, J. G. (1992) “Effective tutoring techniques: A comparison of human tutors and intelligent tutoring systems”, *The Journal of the Learning Sciences*, vol. 2, pp. 277-305.

Nelson-Le Gall, S. (1981) “Help-seeking: An understudied problem-solving skill in children”, *Developmental Review*, vol. 1, pp. 224-246.

Nelson-Le Gall, S. (1985) “Help-seeking behavior in learning”, *Review of Research in Education*, vol. 12, pp. 55-90.

Oblinger, D. G. and Oblinger, J. L. (2005) “Educating the Net Generation”, [online], EDUCAUSE, http://www.educause.edu/educatingthenetgen [June 2006]

Person, N. K., Kreuz, R. J., Zwaan, R. A. and Graesser, A. C. (1995) “Pragmatics and pedagogy: Conversational rules and politeness strategies may inhibit effective tutoring”, *Cognition and Instruction*, vol. 13, pp. 161-188.

Prensky, M. (2001) “Digital Natives, Digital Immigrants”, *On the Horizon*, vol. 9, no. 5, pp. 1-6.

Putnam, R. T. (1987) “Structuring and adjusting content for students: A study of live and simulated tutoring of addition”, *American Educational Research Journal,* vol. 24, pp. 13-48.

Rogoff, B. (1990). *Apprenticeship in thinking: Cognitive development in social context.* Oxford, UK: Oxford University Press.

Scardamalia, M. and Bereiter, C. (1991) “Higher levels of agency for children in knowledge building: a challenge for the design of new knowledge media”, *The Journal of the Learning Sciences,* vol. 1, pp. 37-68.

Tall, D. (1993) “Students' difficulties in calculus”, *Proceedings of Working Group 3*, 7th International Conference on Mathematics Education, Québec, Canada, pp. 13-28.

van de Sande, C. (in preparation) “A comparison of face-to-face and online tutorettes in the Calculus”. Unpublished manuscript, Learning Research and Development Center, University of Pittsburgh, Pa.

van de Sande, C. and Leinhardt, G. (2007) “Online tutoring in the Calculus: Beyond the limit of the limit”, *Éducation et Didactique*, vol. 1, no. 2, pp. 115-154.