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Facilitating Inquiry-Based Science Learning Online in a Virtual University

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Abstract

The authors reviewed their approaches to facilitating inquiry-based science courses from 2005 through 2010 in a fully online master's degree program at Walden University designed to help teachers bring inquiry-based science to their students. The purpose of this paper is to illustrate their interaction-engagement approach in facilitating online courses, which focused on a guided inquiry approach to build understanding of core science concepts using hands-on experimental science investigations.

Keywords: Science education, inquiry-based science, hands-on, e-learning, online classroom, community of learners, discussion boards, teacher professional development, graduate program, distance education, virtual university.

Introduction and Purpose

Online learning has become a rapidly expanding industry (Becker & Posner, 2012; Rowe & Asbell-Clarke, 2007), which offers the convenience of professional development options to working adults, especially practicing teachers, without having to give up their full-time jobs or uproot their families and relocate to a traditional campus. The proliferation of offerings and options in online education programs exacerbates the need for research into the nature and effectiveness of teaching and learning in such environments.

The purpose of this paper is to illustrate the authors' interaction-engagement approach in facilitating online courses, which focused on a guided inquiry approach to build understanding of core science concepts using hands-on experimental science investigations. The graduate-level courses were taught during 2005 through 2010, entirely online, at Walden University. The course participants were practicing teachers who were enrolled in the K-8 Science Specialization of a Master of Science in Education degree program.

Learning science through an inquiry-based approach involves active 'hands-on' and 'minds-on' learning that centers on questioning, collection and analysis of data, and critical thinking (Olson & Loucks-Horsley, 2000). By 'hands-on' and 'minds-on' learning, it should be understood that:

> Students do their learning by working with their hands, not just by watching and copying what the teacher writes on the white board, not just by reading workbooks and filling in blanks, but by thinking, learning, designing, building, by experimenting, by doing. (Dizon, Hoop, & Morgado, 2003)

The concepts of learning by doing and thinking are the cornerstone of authentic science learning, not only for children, but also for adults in a graduate-level program. Furthermore, adult learners draw upon their accumulated experience (Knowles, 1990) in the process of learning. However, learners' previous knowledge and experience can serve both as a resource for linking new information, and as an impediment when previously-held misconceptions persist. In the context of learning online, participants share ideas, pose questions, and seek clarification via discussion boards within their online classroom. Over time, they learn from taking an active role in discussions with others, leading to what Pea calls *distributed* intelligence (Pea, 1993).

Meaningful learning will only take place if it is situated in "authentic [and purposeful] practices through activity and social interaction" (Brown, Collins, & Duguid, 1989, p. 37). By participating in a *community of learners* (Brown & Campione, 1994; Rogoff, Matusov, & White, 1996), learners can share data from their experiments, discuss the common pattern in their results, question discrepant data, challenge misconceptions, and form evidence-based conclusions. In so doing, the learners with greater prior knowledge join the facilitators in taking on the role of the *more knowledgeable other* (Vygotsky, 1978) to facilitate the development of those with less prior science knowledge, while further reinforcing their own understanding.

Methods and Approaches

The online courses were part of the Science Specialization of a Master of Science in Education Program (M.S.Ed.) for elementary and middle school teachers offered by Walden University between the year 2005 and 2010. This program was developed by Technical Education Research Centers (TERC), a leading educational research and development organization committed to improving the teaching and learning of science in schools, with funding from the U.S. Department of Education Fund for the Improvement of Postsecondary Education (Doubler & Grisham, 1999).

It was presumed that teachers undertook this graduate program to improve their content knowledge, as well as for their professional advancement in their teaching careers and, for some, financial incentives from their state. The courses in this graduate program integrated science and pedagogy; the science and pedagogy components of the courses were facilitated by two different people online: a scientist and a science educator. Most of the program participants were employed fulltime as teachers. For this reason, the weekly sessions began on Fridays to enable them to start their hands-on investigations during the weekend.

The 13-week introductory course in this Master's program was known as *Try Science* (Harlan & Altobello, 2003). The purpose of this and other courses in the program was to develop teachers' understanding in science and improve their pedagogic skills relating to teaching and learning science through inquiry. A guided inquiry approach was the underlying theme that permeated this course and, as illustrated in this paper, was reinforced throughout other courses in the entire program of study.

In the first six weeks of *Try Science*, the focus was on learning science, while the next seven weeks focused on facilitating the learning of science. During the first half of the course, participants conducted hands-on science investigations each week and discussed the significance of their findings in online discussion forums. After the first week, participants were divided into groups of six or seven and were expected to respond each week to the posts of others in their group via the online discussion boards, facilitated by the instructors. As the course progressed, an increasing amount of time was dedicated to learning strategies for bringing inquiry-based learning to the classroom. In the final weeks, the participants applied what they have learned in this model by designing and trying out a lesson with their students. A report on this experience was posted by each participant and evaluated by the peers and instructors. Participants continued their study in this Master's program with the second course, known as *Investigating Physics*.

A challenge often encountered in an online introductory science course that employs methods of experimental inquiry is the wide breadth of science background preparation and experience among enrolled participants. This disparity in backgrounds has the potential for high attrition among participants in a first science course of study, who have not had as much science content knowledge and "hands-on" experience as their classmates.

In an online setting, participants with substantial prior science preparation, who fall into this latter category, may serve as a useful resource in assisting classmates with interactive-engagement discourse to facilitate their learning. That is, a form of peer support among participants enables those with less prior knowledge and experience to grasp science concepts to help them overcome some of the difficulties associated with learning college-level experimental science content for the first time. The facilitators scaffold the participants' learning by posing questions, probing, prompting, highlighting discrepancies and stimulating further thinking.

Since the approach was in formally promoting interaction-engagement among participants with diverse backgrounds and preparation in an online introductory science course, there was an interest to learn how well this teaching approach carried over among participants in a subsequent science course, not only to assess an understanding of the material on the part of participants with diverse backgrounds, but to foster unique teaching and leadership experiences.

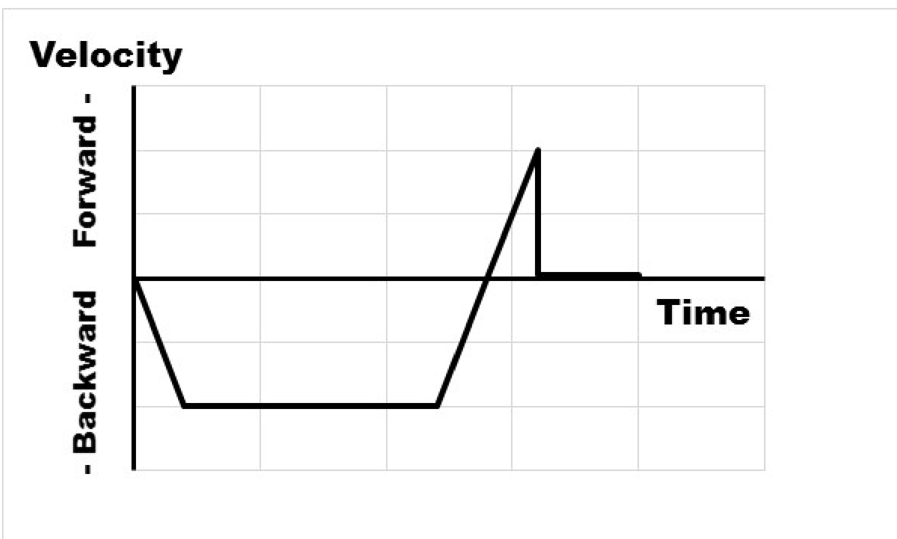
The authors had hypothesized that the postings by participants and facilitators in the peer group discussions would encourage interaction and engagement among participants, especially for those who might have perceived themselves at a disadvantage with respect to some of their classmates, and enhance their self-confidence in continuing to pursue their online education endeavor. Encouraged by their success with participants in several semesters of *Try Science*, the authors reinforced the practice of interaction-engagement, as well as recognized among participants the pedagogical value of peer support, in a subsequent course called *Investigating Physics*.

As in their first course, participants were divided into small groups and were expected to respond to each other via the online discussion boards, facilitated by the instructors. Having experienced a similar process in the first course, participants were already familiar with the norms, expectations, and benefits of online peer group discussions. This approach was continued throughout the course as well as throughout the rest of the Master's program.

Interactive –Engagement Examples

In the following two examples from *Investigating Physics*, participants were studying graphical representations of motion. A graph of velocity vs. time was presented (Fig. 1).

Figure 1 Velocity vs. time graph (referred to in text as "Motion Story #4") to be interpreted by a narrative (story) of the motion represented (Adapted from Rubin & Doubler, 2002).



Participants were asked to first label each portion of the graph with the kind of motion behavior it represented. Each participant was then asked to write a story in their journals involving motion that corresponds with the graph. Their motion stories were required to involve forward and backward motion along a single straight track. Participants were invited to use their imagination. Following their stories, participants were invited to share insights and questions with their classmates. All names of participants are fictitious.

In these examples, note the specific science concepts raised by the participant storytellers Heidi and Susan, the interaction and feedback provided by other classmates, and – most importantly – the minimal but timely and critical encouragement by the Instructor.

Example 1

HEIDI: *Motion Story #4 Sequence: rest – speeding up at a fast rate in a negative direction – high speed constant in a negative direction – abrupt slowing down in a negative direction – stop – speeding up at a fast rate in a positive direction – abrupt slowing down in a positive direction – rest*
Story: I am resting in my kayak in the water watching the magnificent glacier towering before me. The water, protected by the natural walls of the fjord, is perfectly still. A loud, thunderous "BOOM" erupts from the large ice mass. I quickly turn my paddle in the water and move the kayak backwards just in time to avoid a chunk of ice that falls inches from the front of my kayak. My kayak continues to propel backwards. It reaches the fastest speed I can manage and endure for about a minute. My arms finally tire and I realize I am now out of harm's way so I use my paddle to quickly slow down the kayak to a stop. As I am doing this, I notice a sea otter surface about 100 feet in front of me. I use all of my power to propel the kayak forward in the otter's direction. I stop abruptly as it dives down out of sight. I wait for a while, but the sea otter does not resurface.
Insights: This activity made me realize how motion can change dramatically. I never thought about all of the rates of acceleration: quickly speeding up, gradually slowing down, etc. It makes motion seem a bit more interesting and I actually enjoyed interpreting the graphs and writing these stories. I could see how this activity might arouse the students' curiosity and provide a means for them to explore within their own experiences.
Questions: It is still difficult for me to comprehend the change from negative velocity to positive velocity. When I first studied this graph I thought that the constant speed in a negative direction suddenly shifted to an acceleration in a positive direction. However, I realized that it was still negative so that didn't really make sense. I then determined that the object must have been slowing down quickly, stopping (very briefly) and then propelling forward quickly. I am still unsure as to whether or not the object actually stops or if it is just a sudden motion from negative to positive without an actually stop. I know a kayak doesn't really stop in the water because it continues to glide in the water. I use my paddles to start churning the water in the opposite direction as the kayak continues to glide. I know that I must stop, but I don't think anyone observing would even be able to notice that the kayak actually stopped before it began propelling forward, especially if I went full power.

INSTRUCTOR: *Glacier ice peril! Solid sequence, and engaging story, with very thoughtful questions, Heidi! Your Groupmates may wonder whether graph #4 indicates the motion you executed to cover the distance of "100 feet" back to where the sea otter surfaced. Further thoughts, Groupmates?*

HEIDI: *Distance. This comment makes me wonder about how we can apply distance into these graphs. I really didn't want to put a number in my story, but I figured it would give a better visualization. I didn't exactly cover the distance of*

100 feet in my story because I said that I stopped abruptly when I saw the otter go back under the water. The reader may or may not assume that I covered the entire distance. That is left for interpretation. I just want to know anyone else's thoughts on how distance is applied to these graphs. Thomas and Amy used some short distances for reversing... out of the parking spot... out of the garage. I think the constant speed might be a further distance such as driving down the road. It is definitely a further distance than the driveway. I don't think we can put a cap on the distance traveled since this is not a distance over time graph. I think anything might be okay as long as it works proportionately with the other motion changes on the graph. Any thoughts?

CHARLES: *First of all, great story! Do you write in your free time? Anyway, I don't think any sort of distance can be applied here. I think the only label that could be applied might be a time interval, seconds, minutes, hours. I'm not sure how speed could be labelled on the Y-axis because we are not talking about a distance here. Since speed equals distance divided by time, not sure how we could incorporate a distance in the graph?*

SUSAN: *When I was looking at the distance I didn't concern myself with a number. The graph could represent a great distance or a short one. I thought about using my train trip across country. Distance could be measured in small or large units and time could be the same. Whether you covered the entire distance to the sea otter is not as important as where you ended in relationship to where you began. It was a great story by the way.*

HEIDI: *Susan, here's a question for you: "…where you ended in relationship to where you began" - you stated this was important and I also saw that you wrote about it in another post. Not sure I understand what you mean. Do you mean that my kayak should be back at the spot where I observed the chunk of ice falling? Or do you mean that I just need to follow the sequences on the graph and they may not necessarily take me back to my original position. Since we are not applying distance it would make more sense to me just to follow the sequence of motions to see where I might end up. It may or may not be where I started. Please elaborate on your thoughts.*

SUSAN: *I have been looking at the y-axis in terms of distance and speed. I am not sure that is correct though - and if it is I would need to think through things again since the positive acceleration goes past the original starting point. I am beginning to think that I am over analyzing it. I even started to talk about it in the middle of another conversation with my husband. He looked at me like I had lost my mind.*

CHERYL: *Heidi, I think that until we qualify the time piece- are we measuring in minutes, seconds?- the distance is open to interpretation. Obviously, it we are using seconds, the distance covered will not be great. What size increments we* *are using will also have an impact- are we increasing singly, doubly, etc.? Without these details, it is tough to say what the distance in any given story is. What do you think?*

HEIDI: *I suppose distance doesn't really matter at this point since we are really just focusing on velocity and time. I understand what you are saying about the increments of time. We aren't being so specific yet... that might be a lesson for later on :)*

THOMAS: *Heidi, I am in agreement with you. I feel that by adding in distance and other components to the whole motion picture it would be easier to figure some of these situations out. I think that for now they just want us think about motion in general. I know that there are many forces that affect motion but right now I do not think we are taking all these forces into account. Some of the forces that affect motion could be friction, gravity, inertia and other factors such as distance and velocity.*

HEIDI: *Ideas that we will get to... I just get ahead of myself I suppose. I did mention it in my story so I felt like I needed to explain it.*

HEIDI: *More questions. Okay, thanks to everyone I have more insight into the distance issue. It appears that most of you don't think it is a concern at this point since we are dealing with velocity and time. That raises a new question: Why are there concerns about getting back to the starting point if we are not discussing distance? The graph in no way implies that you must return to where you started. It does imply that you must return to a stop (or in the case of Thomas's interpretation, a very, very slow constant speed). Second, I still have the question about the shift from a negative velocity to a positive velocity. I see that most of you implied that it was a quick backward direction, stop and then a quick forward direction (the line that intersects the "time" axis). However, I know that not everyone interpreted it that way. Thoughts about that? Lastly, there are still some concerns about what it really means to be at negative velocity. In my opinion and from what I have read, I think negative velocity means that the object is just going in a negative direction. It may or may not be facing backward. Also, one person's idea of a negative direction might not be the same as someone else's idea of a negative direction. I think the only concern in this case is that you clarify the positive and negative.*

SUSAN: *I think you are right about negative velocity simply meaning going in a negative direction and that there must be a reference point. We could both be observing the same motion but from different positions. As I consider the area of the graph where there is a shift in velocity I think this is where I began to think of the idea of distance. When I first considered the graph I interpreted that segment (above and below the time line) as going in the same direction. Then since part of the line was negative I then decided that it was indicating a slowing down[.]*

AMY E: *Stopping*
The line show the object slowing (with - v) and crossing the x-axis point with a 0 v and then continuing on to speed up (with + v). So depending on the time intervals, for a split second the object must have stopped, otherwise how could it have changed to an opposite direction. Maybe if the object changed from going North to West, it wouldn't have to stop, but if it is going the exact opposite direction, I would think that everything would have to stop - even if it's hardly visible. I think about that a lot when playing/officiating/coaching a setter in volleyball. If the ball rests, it would be considered illegal. BUT, the ball must rest/stop at some point in order to change directions.

Example 2

SUSAN: *Motion Story #4*
Sequence: Stopped; Fast acceleration backward; Constant speed backward; Slowing down backward; Fast acceleration forward; Sudden stop; Remain stopped
First story idea: You are in your garage getting ready to back out. You put your car into reverse and quickly back out of the garage. Once out of the garage you reach your desired speed and continue to back out of the driveway. When you reach the end of the driveway you quickly slow down as you back into the street. Suddenly you realized that you did not notice an approaching car. You quickly throw the car into drive and quickly move forward into the driveway. As soon as you are back in the driveway you quickly stop the car and remain stopped until the danger has passed.
Second story idea: A gymnast is standing at the corner of the floor mat facing outward. She is poised to begin her sequence back across the mat. She does three quick flips and then completed a series of summersaults continuing her journey across the mat. As she reaches the center of the mat she slows her movements with another flip to get ready for another sequence. When she lands, she fails to stick her landing and takes several steps forward before coming to a stop.
As I began to work on this week's assignment I realized that I had never stopped to think about how complex motion is in our lives. Things rarely move in one direction. Picking apart the motion was difficult. Grappling with it in graphic representations was even more difficult.
As I wrote my stories I first questioned if I was interpreting the graph correctly. I am still not certain that I have done so. I would work on it and then set it aside and then go back to it. I would label and re-label the segments. The other question that came up was regarding movement in other directions. Things do not just move back and forth on a straight track. Things also move side to side and in circles and at variable speeds. How would that look like on a graph?

INSTRUCTOR: *Floor routine interrupted! Solid and clear sequence, Susan, which make both of your stories easy to follow. We'll bet your Groupmates will have some interesting comments.*

SUSAN*: Story Revision[.] As I continued to think about and review the graph, I decided that the graph shows the moving objects as beginning and ending in the same location. I have made minor revisions to reflect this interpretation. By the way - my husband says I am talking about graphs in my sleep.*
First story idea – revised: You are in your garage getting ready to back out. You put your car into reverse and quickly back out of the garage. Once out of the garage you reach your desired speed and continue to back out of the driveway. When you reach the end of the driveway you quickly slow down as you back into the street. Suddenly you realized that you did not notice an approaching car. You quickly throw the car into drive and quickly move forward into the driveway and into the garage. As soon as you are back in the garage you quickly stop the car and remain stopped until the danger has passed and your heart stops pounding.
Second story idea – revised: A gymnast is standing at the corner of the floor mat facing inward. She is poised to begin her sequence back across the mat. She does three quick flips and then completes a series of summersaults continuing her journey across the mat. As she reaches the center of the mat she slows her movements with another flip to get ready for another sequence. When she lands, she reverses her direction and executes several back flips until she is once again in the corner. She stops in the corner and stands in her final position.

INSTRUCTOR: *Floor routine completed. Groupmates? Does Graph #4 show Susan's gymnast getting back to the corner?*

SUSAN: *I'm not sure after reviewing again. I keep looking at it and keep coming up with different answers. I am beginning to confuse myself.*

HEIDI: *Susan, after reading other stories and pondering my own questions, I realized that we all have our own interpretations of the graph. Granted, we are trying to come to an agreement (like scientists do), but our limited knowledge (speaking for myself at least) may be a factor. Thomas made a good point of stating that we have just not reached the next level. I know it is difficult to be confident when we can't always fit the pieces together, but think about how this will play out in the classroom. Exploration is so much fun and the students will learn to question themselves and they will also learn how to make good arguments to support their findings. I tend to over-complicate things so I have to be firm about sticking to one idea and building on that instead of trying to do too many things at once. If you are dreaming about graphs then you might also be overanalyzing :)*

SUSAN: *I know I am and my husband keeps telling me to relax. This is a learning process and going through it helps me to be more empathetic towards my students who struggle.*

HEIDI: *I admire your passion and commitment.*

SUSAN: *Amy E's ideas helped me see the graph more clearly. I think I was closer in my first story. In my revision I got my sense of distance mixed up. Thanks Amy.*

AMY B: *Susan, I think the gymnast idea was very creative. Your story makes me picture the gymnast doing flips on the map. I think you were more correct with your first story as well. You seem to be getting caught up on the fact that the graph returns to the same point, for example, the line returning to zero. I believe that the position does not matter, we are talking about speed. The speed returns to zero. It can be stopped anywhere.*

CHERYL: *Susan, I too question some of my interpretations of the graphs. I tried to walk the graphs (I am a kinetic learner at times) to see them more clearly, but I am totally confident in my abilities yet. It would be fun to create a huge graph, put ink or paint on the bottom of our feet, and create a motion graph (I know this would appeal to kids.).*

SUSAN: *A huge graph would be fun but I would want to be a little more confident in my interpretations first or I would have a giant mess. I am also a kinesthetic (and visual) learner. It didn't think about walking the scenarios out. I will have to try that. I did use my cart and Hot Wheel cars a lot.*

THOMAS: *Susan, in your first story idea about motion graph 4, in the last part of the story you say that, "As soon as you are back in the driveway you quickly stop the car and remain stopped until the danger has passed." You indicate that the graph shows the last motion as a complete stop. When I looked at the graph I noticed that the end of the graph shows a constant speed line very close to the line where you would normally be at rest. When I looked at this graph compared to motion graph 1, motion 4's line did not touch the at rest line as it did in 1. I took this as you would slam on the breaks but would continue at an extremely slow constant speed, not coming to a complete stop.*

SUSAN: *I guess that would be a matter of interpretation. I saw it on the line.*

AMY B: *Susan and Thomas, it is interesting the different interpretations of the graph. I interpreted it the same as Susan that the graph returned back to zero and was on the line for a period of time. I had to go back and take a second look. It is very hard to tell whether it is on the line or just above it.*

> AMY E: *Susan, I really like your gymnast story! That would be a neat one to record and play in slow motion. I do wonder how the up/down motions affect the velocities (-,+) and accelerations. Putting it in a strobe picture would be interesting - last week I was watching the ball a little when it first came off the cart and bounced. I wonder if a gymnast's forward motion would be affected similarly. I have a whole new appreciation for what gymnasts must go through in order to make a routine work physically!*

Discussion

The above two examples substantiate the pedagogical merit of guided hands-on inquiry-based science learning in an online environment. The course participants actively engaged their peers as they sought to make meaning of the science concepts via the discussion boards in the online classroom, aided by the course facilitators. It is evident that group discussions and facilitators' postings that foster interactive engagement support collaborative learning among participants in online discussion boards.

The authors of this paper further believe that hands-on inquiry learning in an online environment can simultaneously improve intellectual and communication skills. Evidence to support the validity of this conjecture will, of course, require a thorough long-term investigation and follow-up of students in subsequent online educational experiences. However, as mentioned in the Introduction and Purpose section, in this study the authors observed promising indication of concepts being grasped among students of science who are encouraged to engage each other in earnest discussion. Moreover, as they nurtured this engagement, they observed that from the start of a course to the end, their collaboration and contributions as instructors encouraged students to continue to mature in their approach to scientific inquiry.

Concluding Remarks

While this report clearly does not constitute a thorough research approach, it is meant to serve as an illustration of what the authors believe was an effective collaboration, over a brief period of time, worthy of further systematic study. Collaboration between a science educator and a scientist assigned to the same course in an online environment required recognizing and developing a common learning philosophy. The authors found themselves continually learning from their own, and from each other's experiences, and thereby conveying that to students. They believe the student discussions testify to that, and that therein lies the implication of their efforts and the essence of transferring and disseminating their practice. In brief: the practice of encouraging and facilitating collaborative science inquiry in an online classroom can result in increased interest in science inquiry as a teaching tool. For active educators and researchers alike, this practice engenders better preparation for conducting hands-on science laboratory activities in face-to-face classrooms, and enhanced self-confidence of professional educators of elementary and secondary students in science and math, as well as in other subjects.

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References

Becker, G. S. (2012, November 25). Online courses and the future of higher education [Blog post]. The Becker-Posner Blog. Retrieved from www.becker-posner-blog.com/2012/11/online-courses-and-the-future-of-higher-education-becker.html

Brown, A. L., & Campione, J. C. (1994). Guided discovery in a community of learners. In K. McGilly (Ed.), *Classroom lessons: Integrating cognitive theory and classroom practice* (pp. 229-270). Cambridge: MIT Press/Bradford Books.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32-42.

Dizon, M-G., Hoop, B., & Morgado, A. P. (2003). *Making math real: Integrating hands-on science, math, engineering and technology in an urban 4th Grade classroom.* Massachusetts Charter Public School Association, Boston, MA (unpublished).

Doubler, S., & Grisham, L. (1999). *Establishing an inquiry-based model for online teacher professional development project.* TERC and U.S. Department of Education Fund for the Improvement of Postsecondary Education (FIPSE), Grant #P116D990066.

Harlan, W., & Altobello, C. (2003). *An investigation of "Try Science" studied on-line and face-to-face.* Research Report. Cambridge, MA: TERC. Retrieved from www.terc.edu/downloads/TryScience_Report.pdf

Knowles, M. (1990). *The adult learner: a neglected species* (4th ed.) Houston, TX: Gulf Publishing.

Olson, S., & Loucks-Horsley, S., eds. (2000). *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning,* National Research Council, Washington, DC: National Academy Press.

Pea, R. D. (1993). Practices of distributed intelligence and designs for education. In G. Salomon (Ed.), *Distributed cognitions: Psychological and educational considerations* (pp. 47-87). New York, NY: Cambridge University Press.

Rogoff, B., Matusov, E., & White, C. (1996). Models of teaching and learning: Participation in a community of learners. In D. Olson & N. Torrance (eds.), *Handbook of education and human development* (pp. 388-414). Oxford, UK: Blackwell.

Rowe, E., & Asbell-Clarke, J. (2008). Learning science online: What matters for science teachers? *Journal of Interactive Online Learning, 7*(2), 75-104. Retrieved from www.ncolr.org/jiol/issues/pdf/7.2.1.pdf

Rubin, A., & Doubler, S. (2002). Investigating physics: An intimate look at an online inquiry-based graduate science course. In Gerry Stahl (Ed.), *CSCL '02 Proceedings of the Conference on Computer Support for Collaborative Learning.* International Society of the Learning Sciences, 712-713.

Vygotsky, L.S. (1978). Interaction between learning and development. In M. Cole, V. John-Steiner, S. Scribner, & E. Souberman (Eds.), *Mind in society: The development of higher psychological processes* (pp. 79-91). Cambridge, MA: Harvard University Press.