Examining Teacher Decision Making During Enactments of Novel Technology-Infused Curricula

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Objectives & Theoretical Framework

During the last century, computer-based technologies (CBT) have played a progressively more important role in science. Scientists often employ the latest technologies to further their pursuit of knowledge, while technology further develops as science advances. In response to the benefits that CBT has provided, science education policy makers have called for the integration of computer technologies into the classroom (National Research Council, 1996, p. 190). Due to the increasingly central role of CBT in science, science teachers across the country must be prepared to integrate technology into their teaching practices and teacher professional development programs must assume increased training in the use of CBT (Texley & Wild, 2003). In turn, designers of technology-infused curricula face new challenges that arise from the use of CBT in the classroom and articulation of the role of teachers using technology (Edelson, Gordin, and Pea (1999).

Researchers argue that teachers' integration of CBT into the classroom can promote positive pedagogical outcomes. Teachers use of technology allows them to re-examine their practices (Sheingold & Hadley, 1990) by allowing engagement in collaborative dialogue with peers (Honey & Moeller, 1990), exposing teachers to student project based learning (Becker & Ravitz, 1999; Honey & Moeller, 1990), and using the technology as productivity tools (Dwyer, Ringstaff, Haymore, & Sandholtz, 1994). Studies also report that teachers have positive attitudes towards the use of technology in education. For example, Albirini (2006) study on the attitudes of high school EFL teachers in a large Syrian province towards CBT suggests that the respondents' views towards CBT in education were quite optimistic. However, teachers' perceptions of the integration of CBT with their own pedagogical practices were not as positive. Albirini's conclusion support Willis, Thompson, and Sadera (1999) conjecture: teachers may have positive attitudes about CBT use in education, but they exhibit computer anxiety when they have to integrate the CBT into their own practices and classrooms.

Ropp (1999) and Rovai and Childress (2002) suggest that this computer anxiety can lead to poor integration of technology. Both studies argue that even if teachers perceive the positive benefits of computers, they may not choose to use the CBT curriculum because of their low confidence, fear and dislike of the technology. As a result, a chicken and egg scenario occurs: teachers who are anxious about computers need more technology instruction, but anxious teachers are also unlikely to want to participate in technology instruction (Ropp, 1999). Other negative factors that prevent CBT integration include technical difficulties (Butler & Sellbom, 2002), lack of administrative support (Mumtaz, 2000), cultural beliefs about schooling (Cuban, 1993), standards and accountability pressures (Fishman et al., 2009), and others[1].

These numerous and complex factors undoubtedly shape and influence how teachers integrate CBT's into the science classrooms. In particular, researchers are examining how these factors affect how teachers CBT integration match the intended learning goals. For example,

[1] For an extensive review on factors that affecting teachers' integration of technology see Mumtaz (2000)

Songer, Lee, and Kam (2002) offered a detailed analysis of six unique CBT-infused curriculum implementations that shed some light on the way in which specific local contexts affected the fidelity of curriculum implementations. The results of the analysis suggested that environmental factors pertaining to both a teacher's classroom and school significantly impact the ways in which teachers enact CBT-infused curricula. From among the six cases, Songer, Lee and Kam observed that teachers with the access to the greatest administrative support, technology resources and smallest class sizes implemented novel CBT-infused curricula in a manner more closely aligned with the stated learning objectives and pedagogical principles of the curriculum compared to teachers who lacked administrative support, access to computing resources and tightly constrained curriculum schedules.

Building on these earlier studies of CBT-infused curriculum implementations, we present an analysis of two teacher implementations of a novel computer-based inquiry curriculum for teaching chemistry. Rather than focusing on the environmental factors that shape novel implementations, we ask the question, "How do teachers' strict adherence or flexible adoption of a CBT science infused curriculum support the learning goals of the curriculum?" We examine in detail the particular pedagogical strategies teachers make when using a CBT-infused curriculum with two case studies of two chemistry teachers teaching lessons on chemical equilibrium using the Connected Chemistry Curriculum (Stieff & Wilensky, 2003). With these cases we illustrate the unique ways in which teachers enact curriculum materials in ways that are consistent with the design and pedagogical principles of the curriculum. In the first case, we argue that Mr. Jones appears to follow the curriculum framework assiduously, yet diverges significantly from the pedagogical principles of the curriculum. In contrast, Mr. Davidson makes significant modifications to the daily activities of the curriculum, yet remains highly consistent with the stated pedagogical principles. With these two cases we argue that teachers' apparent divergences from curriculum frameworks may be deviations only in a superficial sense and that teachers who follow curriculum guidelines literally may adapt the curriculum in unexpected ways.

Methods, Materials, Participants & Analytical Framework

We employed a case-study approach (Yin, 2006) to compare two teachers' (Mr. Jones and Mr. Davidson) of use of the Connected Chemistry Curriculum. Mr. Jones is a teacher with less than 3 years of teaching experience working in a school ranked in the fourth decile statewide. Mr. Davidson has over 15 years of teaching experience, working in a school ranked in the seventh decile statewide. For each teacher, we present a case of teaching Le Chatelier's Principle using a guided inquiry worksheet from the Connected Chemistry curriculum. At the core of the curriculum are interactive simulations that present students with a visual representation of the interactions between simulated molecules in a sealed container. These visual simulations allow for students to "observe" the submicroscopic interactions of aggregate molecules. The curriculum situates the simulations with worksheets that help to scaffold observations of molecular interaction (Stieff & McCombs, 2006). Among the design and pedagogical principles of the curriculum two are of interest for the present work: (1) teachers should make strong connections between submicroscopic, macroscopic and symbolic levels and (2) teachers should be explicit about their own level of reasoning during instruction.

A team of three researchers videotaped these lessons during the second semester of a one-year high school chemistry class. The researchers acted as participant observers in the class by providing technical support and student guidance during the enactments. Mr. Jones taught the lesson in two 40-minute periods; Mr. Davidson taught the same lesson in one 55-minute period.

Prior to these enactments, both teachers completed a professional development seminar together on the curriculum and had enacted previous Connected Chemistry lessons earlier in the same academic year.

Analysis of the data involved review of video, transcription and thematizing using a constant comparative method (Strauss & Corbin, 2007). We first approach the analysis by reviewing the video and asking the questions: Who is talking? What is the topic of the conversation? What decisions is the teacher making here at each moment? In a second round of examination, we looked for patterns to identify key themes in the enactment. Lastly, we selected key parts of Mr. Jones and Mr. Davidson's enactments that we felt best represented the themes. Those clips were transcribed into text. We acknowledge that that our transcripts are nonobjective constructs that are not removed from our interpretation (Bird, 2005). There are several limitations to our data. First, the research question was not generated a priori, but instead came out of an initial review of the enactment. Second, Mr. Jones and Mr. Davidson's use of the curriculum was analyzed two years after the enactment. Lastly, due to the length of time between enactment and analysis, our team was unable to conduct interviews and gather multiple sources of data. We rely solely on the analysis of video data and transcripts.

Mr. Jones' Lesson

Mr. Jones' lesson begins with the students using the computer simulations and the inquiry worksheets that accompany the curriculum. In the first activity, the students are working in pairs to make observations of reversible and irreversible reactions (Figure 1). Mr. Jones walks around during this time, helping students complete the worksheet and answering questions. Once the simulation observations are complete, Mr. Jones begins a discussion with his students.

Mr. Jones:	Let's look at reaction 1, does anyone feel confident enough to give me an answer as to whether or not if it is probably reversible or irreversible? (calls on John).
John:	Irreversible.
Mr. Jones:	Ok, and so lines of evidence do you have that would support that decision?
John:	O_2 is used completely up.
Mr. Jones:	Does it ever come back again?
John:	No.
Mr. Jones:	No. It never came back again. We lost one of the reactants. It went away and never came back. So how did you note that? What evidence supported that?
John:	The concentration plots.
Mr. Jones:	The concentration plots showed it went away. And then what else did you choose as evidence?
John:	The only thing, well, the time stopped. The concentration just stopped moving.
Mr. Jones:	Ok, well that's using the concentration plot. What about looking at, at the, submicroscopically? Do you see anything there that supports that? (Rob raises his hand). I'll get you in a second.
John:	I don't know.

Mr. Jones: You didn't see anything on the submicroscopic plot? Ok, Rob what did you see?

Rob: In the submicroscopic plot, once it starts reacting, all the sulfur and all the oxygens flow down to the gas. Once as the sulfur picks up sulfur molecules, or atoms, or whatever it is. And once all that, all the oxygen pairs with all the sulfur, it all stops reacting.

Mr. Jones: So that's when we could see if it stops...

Rob: So that's when all the oxygen makes SO_2.

Mr. Jones: So all of the oxygen went away?

Rob: (confirms yes)

Mr. Jones: And it all became SO_2? Did any of that SO_2 turn back into the oxygen?

Rob: No.

Mr. Jones: Ok. How about the sulfur?

Rob: That stayed as normal.

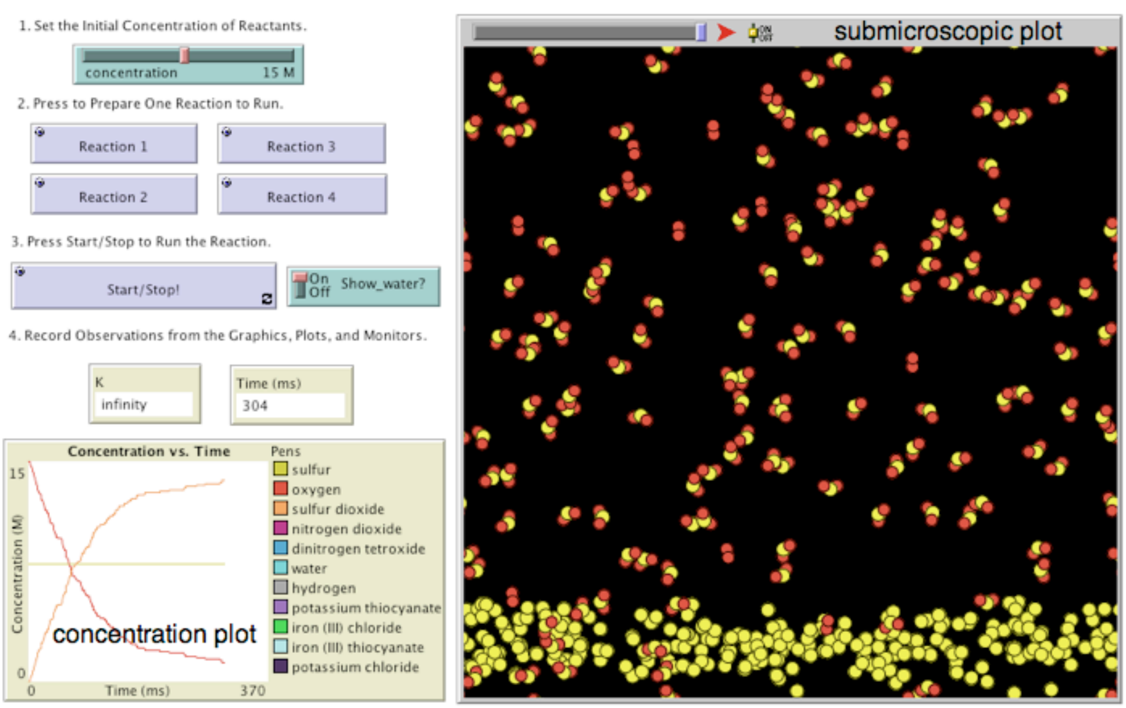
Mr. Jones: Did that stay as solid sulfur?

Rob: (confirms yes)

Mr. Jones: So is that one (referring to the reaction) do you think might be irreversible?

Rob: (confirms yes)

Figure 1: The reaction used by Mr. Jones and Mr. Davidson is $S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$. The students are asked if this reaction is reversible or irreversible. To determine the answer, the students must rely on two pieces of evidence from the concentration plot (bottom left) and the submicroscopic plot (right). The concentration plot shows that as O_2 is being used up, more SO_2 is generated. The submicroscopic plot shows that SO_2 molecules are being produced without decomposing to O_2. The conclusion from these two pieces of evidence is that the reaction is irreversible.



This pattern continues for the rest of the lesson: Mr. Jones presents a reaction, asks for a student to report two lines of evidence (concentration plot first, submicroscopic observation second) and then confirms whether the reaction is reversible or irreversible. While Mr. Jones addresses the submicroscopic observations and symbolic representation, he dichotomizes the two sets of evidence. He offers no discussion that leads students to connect how the concentration plots and the submicroscopic observations are related. Instead, Mr. Jones focuses on having his students agree upon the correct answers to each question presented in the worksheets.

Mr. Jones ends the day by assigning students to read a textbook chapter on Le Chatelier's principle. The next day the lesson begins with Mr. Jones asking students to explain Le Chatelier's principle after writing the symbolic equilibrium expression on the board denoted in Equation 1.

Equation 1. $$(K_{eq} = \frac{[N_2O_4]^2}{[NO_2]}).$$

He explicitly asks the students to describe what they observed about NO_2 and N_2O_4 in the simulation the previous day.

Mr. Jones: What did you do to the concentration of NO_2 (reference to simulation)? This would be on part E.2.1, it would be on the first page of that (looks down on the worksheet).
Jean: Ummm, increase it?
Mr. Jones: Increase it? Which way did the reaction shift? (20-second pause)
Jean: To the right.
Mr. Jones: It shifted to the right. Okay. So…the stress you added is what? The stress is what you do.
Jean: Added it.
Mr. Jones: Added or alter the reactants (points to equation on board $2NO_2 \rightleftharpoons N_2O_4$). So to the thing needed to do to relieve the stress was move to the right.

As the lesson continues, Mr. Jones directly focuses on the manipulation of the symbolic equilibrium expression written on the board.

Mr. Jones: (points to the denominator) So, if we increase the bottom, what has to happen to the top?
Students: Increase.
Mr. Jones: Increase. And is that what you guys experienced (referring to simulation)? Did anybody decrease the concentration of NO_2? Did anybody do that? (Student 2 raises her hand). Yes what did you find?
Student 2: Hmmmm, found that … the N_2O_4 decreased.
Mr. Jones: It decreased as well. So again, would this meet this criteria here? (points to the definition, "adds stress to a system, shift in direction to relieve stress") The stress was you took some of this reactant (points to board) away and to relieve that stress what happened?
Student 3: Some of the N_2O_4 is removed.
Mr. Jones: Some of the N_2O_4 removed, okay.

During the discussion, Mr. Jones uses the worksheets as a pacing guide; he systematically reads each question out loud for the class. Although all the questions have been completed, he does not emphasize connections between the macroscopic, submicroscopic and symbolic levels that are consistent with the design principles of the curriculum, but instead chooses to focus mostly on the symbolic expression on the whiteboard. The questions Mr. Jones asked stayed mainly on the observation level (what did you do, what did you find?). He does not ask the students to make inferences about how the simulations relate to the symbolic representations. Although he enacts the curriculum exactly word-for-word as listed in the worksheet, he does not use the observations of the simulations to make explicit ties to the symbolic representations or macroscopic phenomenon.

Mr. Davidson's Lesson

Mr. Davidson's first lesson is not unlike Mr. Jones' enactment. During the 55-minute period, the students work on the guided inquiry activities in pairs while Mr. Davidson walks around answering ad hoc questions. The lesson begins with a demonstration of the simulation (Figure 1), focusing on the reversibility and irreversibility of the sulfur and oxygen reaction.

Mr. Davidson: What's happening to the concentration, here of the oxygen? Clear down here (points at graph).
Students: It's going to zero.
Mr. Davidson: Yeah, it's gone to zero. With the concentration of oxygen gone to zero, what's happening to the concentration of the sulfur, the pure substance?
Students: It remains the same.
Mr. Davidson: It remains the same. And what do you think the concentration of the sulfur dioxide is?
Dave: 14.8.
Mr. Davidson: Yeah, it's going to stay right up there at a constant. Now is this reaction reversible or irreversible and why?
Bob: Irreversible.
Mr. Davidson: Who said irreversible? (acknowledges student) Why?
Bob: Because the sulfur dioxide isn't going back, it isn't releasing oxygen.
Mr. Davidson: Right. Reversible, some of this sulfur dioxide up here would do what? (refers to submicroscopic plot). It would break down to form sulfur and oxygen gas. That's isn't happening. We are not getting any sort of oxygen gas at all being... so it's only one direction. So we consider an irreversible reaction. Let's look at 500 seconds (refers to concentration plot). All the oxygen is gone (points to graph). We have sulfur dioxide above the sulfur (refers to lines on concentration plot). And the concentration plot, we can go ahead and give the concentration of each of the elements in the compound. And we assume which one stabilizes?
Students: Sulfur. Sulfur dioxide.
Mr. Davidson: Yeah, both of them. And it's an irreversible reaction.

In this portion of the lesson, Mr. Davidson first focuses on the concentration plot, then the submicroscopic observation. Although the students have given the correct answer, Mr. Davidson is not satisfied to move ahead to the next reaction. Instead, he directs the students' attention to the concentration plot to emphasize the relationship between the submicroscopic and symbolic representations. Bob has said that the reaction is no longer releasing oxygen, which Mr. Davidson validates with references to the concentration plot. Despite the fact that the worksheet question asks only for the students to determine the reversibility or irreversibility of each reaction, Mr. Davidson spends significant time emphasizing the relationship between the concentration and submicroscopic plots. Mr. Davidson states that both representations of sulfur dioxide have stabilized in the submicroscopic and concentration plots. While both Mr. Jones and Mr. Davidson students arrived at the same conclusions for reaction 1, Mr. Davidson explanation connects the submicroscopic and the symbolic levels.

In the second lesson, Mr. Davidson begins his class by asking the student to use their worksheets to explore the simulations. During the enactment, he begins to notice that many of the same questions are being asked and then stops the class to begin a discussion on K-values of equilibrium. He writes down the equilibrium expression on the board (Equation 2) and addresses their concerns.

$$\text{Equation 2. } \left(K_{eq} = 0.724 = \frac{[N_2O_4]^2}{[NO_2]} \right)$$

Mr. Davidson: A couple people have said, 'I don't see a shift at all because K would stay at 0.724 (referring to the simulation). So there's no shift. It stayed at this (points to 0.724 on the board). Think about it. If I increase this amount here (points to the numerator) and it stayed at 0.724 in order for that to happen what would have to happen to these two concentrations? They would have to what?

Students: Change.

Mr. Davidson: Change, right? You have an original concentration here and here (points to numerator and denominator) and it's at 0.724. You add some more N_2O_4, the equilibrium constant remains at 0.724. Can this concentration (points to N_2O_4) stay when you add the new one (refers to NO_2)?

Taylor: No.

Mr. Davidson: No. This one (N_2O_4) would have to what? Decrease or increase? It would (points to Sam).

Sam: Decrease.

Mr. Davidson: Decrease, right.

Before the students can finish completing their worksheets, Mr. Davidson begins a lab demonstration of the $2NO_2 \rightleftharpoons N_2O_4$ reaction in the front of the class. He prepares a mixture of NO_2 and N_2O_4 in a piston.

Mr. Davidson: I have a mixture (refers to the piston in his hand) of NO_2 and N_2O_4 (points to the equation on the board). I can increase the pressure on this real easily by decreasing the volume. If I decrease the volume, which way does it shift?

Students: To the left (majority).
Mr. Davidson: To the left. Look (pushes the piston down, the gaseous mixture inside gets darker). Do you see a difference? Watch what happens when I let go of it (releases the piston, the gaseous mixture inside becomes lighter, then darkens).
Sam: It gets lighter.
Mr. Davidson: Did you see it go light and dark again?

Mr. Davidson appears less concerned about completing each activity outlined on the worksheet. Instead of using the worksheets and simulations as a script, he appears to use them as a guide to help students understand the concept of equilibrium. When the simulations are useful, he addresses them directly as in the first excerpt using multiple levels and clearly articulating his level of reasoning. However, he is not constrained by the curriculum. He takes it upon himself to spend more time emphasizing K-values and their relationship to the students' macroscopic observations of the demo than to the students' observations on the simulation worksheets; ultimately, he bridges the gap between the students' observations of the simulations and their conceptual understanding of K-values. Mr. Davidson also ties together the macroscopic observations and the symbolic representation through his lab demonstration. We suggest that although he does not follow the curriculum verbatim, Mr. Davidson ultimately remains highly consistent with the design and pedagogical principles of Connected Chemistry with his own adaptation to the activity.

Conclusions & Implications

Consistent with Squire, MaKinster, Barnett, Luehmann, and Barab (2003) these two case studies suggest that implementation is not a simple process. We believe this analysis provides insights for developers of CBT curricula. As seen in Mr. Jones' class, teachers that are tied too closely to the materials may lose sight of the overarching goals of the curriculum in an effort to make use of the computer technologies. Although Mr. Jones enacts the curriculum with apparent fidelity , we believe that in doing so he diverges significantly from the intended learning objectives of the lesson. In lesson 1, Mr. Jones focuses on arriving at the answer with the sufficient two pieces of evidence, but he does not emphasize the relationship between the submicroscopic and symbolic levels. In lesson 2, Mr. Jones completes all the questions in the worksheet, but again does not go further into connecting the different levels. In the case of Mr. Davidson, in both lessons 1 and 2, he spent significant time connecting the submicroscopic observation, macroscopic demonstration and the symbolic representations. During these lessons, he uses the CBT when applicable using professional judgments. He is able to remain consistent with the goals of the curriculum despite an apparent lack of fidelity in his enactment.

Given these differences, we argue that professional development opportunities for teachers who are seeking to enact CBT-infused curriculum emphasize the goals of the curriculum, rather than strict adherence to the materials (Dane & Schneider, 1998). However, the debate between flexible adoption and strict fidelity continues on. While more flexible adoption allows curricular innovations leads to higher degrees of sustainability, studies have yet to be conclusive on their lasting effects (House, Kerins, & Steele, 1972; O'Donnell, 2008). Although we admit that there are limitations to the data, we argue these two cases demonstrate the need for researchers to examine how high fidelity or flexible adoption affects teachers' interpretations of the core learning principles of innovations.

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