International Journal of Science Education
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tsed20

Challenges to meaningful learning in African-American females at an urban science high school

Phyllis Baudoin Griffard & James H. Wandersee

Published online: 29 Jun 2010.

To cite this article: Phyllis Baudoin Griffard & James H. Wandersee (1999) Challenges to meaningful learning in African-American females at an urban science high school, International Journal of Science Education, 21:6, 611-632

To link to this article: http://dx.doi.org/10.1080/095006999290471

INT. J. SCI. EDUC., 1999, VOL. 21, NO. 6, 611–632

RESEARCH REPORT

Challenges to meaningful learning in African–American females at an urban science high school

Phyllis Baudoin Griffard and James H. Wandersee, Department of Curriculum and Instruction, Louisiana State University, Baton Rouge, LA, USA

This case study sought to identify factors that adversely affect meaningful learning in two African–American female high school students. Tanisha and Latanya are motivated, confident students in an urban, public half-day school for math and science ('Sci High'). Observations of classrooms at Sci High and their home schools, analysis of learning artifacts, school statistics and student records, clinical interviews with the students and interviews with teachers and administrators provided evidence of a lack of metacognitive awareness and realistic self-appraisal. The emerging themes indicate a cycle of cognitive disengagement that is perpetuated by complex cultural factors that permit cognitive passivity, generic motivation (or confidence-without-competence), and attention to behaviour over learning. It appears that without cognitive engagement, neither intentional, meaningful learning nor metacognitive awareness can develop. The findings are presented in an analogical graphic summary that facilitates discussion and analysis.

Introduction

Successful application of the findings of science education research to classroom practice can be affected by large class sizes, highly variable teacher preparation, inadequate facilities, conflicting administrative agendas, and lack of an academic and social safety net for students historically at risk for failure. What if these mitigating conditions in urban public schools were ameliorated? Suppose motivation is high, discipline is managed, classes are small, students of mixed abilities and cultures learn together, teachers have advanced degrees in the sciences they teach, and generous academic support, counselling, and educational equipment were available. What latent challenges reveal themselves as yet to be overcome?

This is a comparative case study of two students learning in such an improved environment. Latanya and Tanisha are students at a public half-day science and mathematics high school ('Sci High') in a large metropolitan area in the deep south of the USA. They were selected because they were well-matched in many regards. They were students in the same Biology II class, both plan to attend college, and both hope to become paediatricians. They have similar socioeconomic and family education backgrounds. The study was not intentionally focused on African–American females *per se*; any matched pair of students of any race or gender could have been selected.

International Journal of Science Education ISSN 0950–0693 print/ISSN 1464–5289 online
http://www.tandf.co.uk/JNLS/sed.htm
http://www.taylorandfrancis.com/JNLS/sed.htm

The primary question driving the study was: 'What challenges to meaningful learning persist in a special science high school that provides an interactive, stimulating environment in which to learn science?' For the purpose of this study, our operational definition of 'learning science' is the mental construction of a set of interrelated propositions related to a natural phenomenon that also has associated links with other such constructions about other phenomena. This is a blending of definitions for meaningful learning (Novak and Gowin 1984), conceptual change (Posner *et al*. 1982), and a constructivist view (Fensham *et al*. 1994) of science education.

To gain clarity about the learning outcomes in this urban science high school, Latanya's and Tanisha's understanding of recently studied topics in their biology class were probed in clinical interviews and analysis of their learning artifacts. These data led us to investigate the school and classroom conditions that permit the gaps in learning observed. Therefore, interviews were conducted with Sci High teachers, staff and principals, and with 'Nia', a successful African–American biology student at 'Liberal Arts U' who has a similar background and career goal as Tanisha and Latanya, and is by all available indicators a meaningful learner. A set of potentially causal themes emerged in the findings that are presented in an analogical graphic to facilitate study and discussion.

Methods

The design and fieldwork for this university-based study was carried out by a doctoral student in biology education with a background in teaching biology at a Historically Black University ('Premed U') with a record of success in undergraduate science education. The analysis was done in collaboration with a researcher with expertise in learning theory and use of graphics in science education.

The study was of a traditional design for a naturalistic setting: participant and non-participant observations in the Biology II and other classrooms were followed by formal and informal interviews with Tanisha and Latanya, teachers, staff, principals and Nia. Archival data and documents, and artifacts of learning (e.g. handouts, worksheets, journals, written examinations and writing assignments) were collected throughout the study. Approximately 25 visits to Sci High were made, each lasting from 20min to 3h, but usually about 1.5h long. Field notes were collected after visits to the students' home high school biology classrooms as well.

Selection of participants

Permission to conduct the study was obtained from Sci High's principal, Eleanor, the Biology II teacher, Kevin, the district's Office of Accountability, and from parents of students in Kevin's Biology II class. The Biology II class at Sci High was chosen as the participant pool because the students taking this elective have the most experience at Sci High, and because the authors' expertise and experience are in biology and biology education. Both sections contained several potential pairs of students who would be well-matched for race, gender, socioeconomic status, work attitude and approachability. The teacher of both sections, Kevin, has many of the characteristics desired by many in a high school science teacher: a strong content background (he is a doctoral candidate in zoology); a history of

student advocacy; a passion for teaching and an interest in conducting education research in his career. The selection of the case study participants was not restricted to African–American females. However, Latanya and Tanisha were selected because their backgrounds and career goals were better matched than other pairs in the class. Since a question in the study early on asked about their home high schools' influence, a contrast in that regard was a factor in the choice of them as participants.

Measures to ensure trustworthiness

The trustworthiness (Lincoln and Guba 1985) of the data collected and interpretations of them was enhanced by incorporating multiple levels of checks into the study design. Foremost was the use of multiple data sources and prolonged engagement in the Sci High environment. Emerging theories based on observations, interviews and document analysis were substantiated by intentional follow-up lines of inquiry with the participants, Sci High's principals and teachers, and Nia. Member checks were made with the principal, Eleanor, and the teacher, Kevin, who were both eager to participate in the study and learn from the findings. Nia's review of the full case study and abundant feedback were valuable for validating some findings and reinterpreting others. Trustworthiness was also enhanced by the close match of the cases with regard to many dimensions (except academic record), the diversity of the data sources, and the relatively close adherence to the case study protocol (Yin 1994), although the question driving the study changed as themes began to emerge.

Sources of bias

The first author's involvement in the establishment of the school six years ago is one possible source of bias, however, there is no benefit to her in putting forth a positive or negative evaluation of the school. Also, some events were reminiscent of her experiences teaching introductory biology at Premed U and may have biased later observations. Since these memories were elicited as they converged with observations, they may instead have served to triangulate the data and support the emerging themes rather than lead or influence them. A third possible source of bias is reliance on Eleanor and Kevin for checks on the findings. A professional affinity to them as like-minded educators may have led us to unduly value many of their sensitivities and priorities about their work.

Interviews

All scheduled interviews were audiotaped and transcribed. Field notes were audiotaped following unscheduled interactions. The interview guide approach (Patton 1990) was used for both interviews with Tanisha and Latanya. Before beginning the first interview with Latanya, it was explained that the project involved interviews rather than just filling out surveys to find out information. She indicated other students' reluctance to take part in either type of inquiry because of what they fear the information will be used for.

At the first interview, each participant was asked directly or indirectly about her peers' and family's regard of her choice to come to Sci High, her work ethic,

confidence and role models, her evaluation of the quality of science instruction at Sci High and her home school, her hobbies and extracurricular activities at both schools, and her aspirations for the future.

After the first set of interviews, a second interview guide was designed to test some of the emerging themes. Among these was a notion that the learning had not been meaningful in their Biology II class, and that their self-evaluation/metacognitive skills were underdeveloped. This clinical interview included questions and tasks in which each student's understanding of biology concepts could be probed (Novak and Gowin 1984). The interview guide included questions about a recent class activity intended to demonstrate morphological advantage in foraging. There were also questions about their class notebooks, cloning science fiction story, and their independent research projects (annual requirement of all Sci High students).

Several Sci High teachers were interviewed to obtain their opinions about Tanisha's and Latanya's abilities, as well as to find out how they evaluate their students' understanding of the content they teach. This line of inquiry was framed as 'How do you know that your students understand?' Following these, the Sci High principal was interviewed to obtain her opinion of how Sci High teachers assess knowledge and what the challenges to learning at Sci High are. Her responses provided strong support for the emerging ideas about Tanisha's and Latanya's learning weaknesses. A videotaped interview with Nia about her success as an African–American woman aspiring to be a paediatrician also shed light on high school learning and the transition to college. Nia was interviewed once again to solicit her remarks about the findings of the entire case study.

Document analysis

Data (in the form of a 'report card') for Tanisha's and Latanya's home high schools were obtained from the school district's accountability office. The state does not produce a report card for Sci High since it does not grant diplomas. The district's annual guidance counsellor's report provided some home school data, e.g. graduation rate, rate of honours awarded, and rate of college/remedial class enrolment. Some information came from the schools themselves: counselling offices provided race information and cafeteria supervisors provided data on free lunch recipients. Sci High staff members have said that it is difficult to obtain statistics for the Sci High student body as a whole, since college entrance exam scores and state exit exam scores are sent only to the home schools.

The official school files for Tanisha and Latanya are kept at their home schools. Those at Sci High contain only Sci High-related information. Supervised access was granted at their home schools' counselling offices. The information most useful from these files was college entrance exam data, which provided an interesting look into their predictions about their college experience.

A photocopied Sci High school profile brochure provided a mission statement, but a professionally produced brochure from the school's advocacy organization sings the praises of the novel curriculum to would-be donors. Another flier, the 'What we are and what we are not' sheet, explained how Sci High is different from many district schools, particularly in work and discipline expectations of students. The discipline booklet and contract goes to each student and must be signed to signal agreement with the terms of enrolment at Sci High.

To get an idea about Tanisha's and Latanya's conceptual framework for topics they had recently studied in Kevin's class, we relied on analysis of their learning artifacts. These documents included the contents of each of their class journals, their independent research projects and a recent writing assignment, which was a short science fiction story about some application of cloning. Their short stories as well as two other exemplary stories from magnet school students were analysed for scientific correctness and sophistication. Artifacts of their learning not only provided information about their cognitive structure, but were also exploited as probes during the clinical interview, as stated previously.

Nia's annotation of and written comments about the full case study were also considered in the analysis.

Findings

Tanisha

Kevin describes Tanisha as hard-working, capable and approachable. Tanisha's file indicated she is an average student without excessive absences, and showed a gradual change in attitude and success. In 1995 she was chosen by the principal to attend a city-wide luncheon honouring public school students selected as 'most improved' at their schools. She is now earning Bs and Cs at Sci High, but her performance on national standardized tests is low: 29th percentile in reading, 14th percentile on the California Achievement Test (CAT) in math and 15th percentile on the science section. In spite of this poor showing, she has gained admission into two state universities. This has been a surprise and a concern to Sci High's college advisor who is not sanguine about Tanisha's prospect for success.

Tanisha's work in Kevin's Biology II class and her Sci High Astronomy class was reviewed. The topics discussed in the Biology II class during the study were gene expression, development, natural selection/evolution and ecology. Although Kevin requires that they keep a notebook, the items in Tanisha's were identical to Latanya's, indicating that although the information was at a high level, it was probably either copied from the chalkboard or their textbook in response to an assignment. The notes (dated a month earlier) in both girls' notebooks included molecular structures for the major groups of biomolecules (proteins, carbohydrates, nucleic acids and lipids) and descriptions of groups of lower organisms.

The assigned science fiction short story Tanisha wrote about cloning, 'Attack of the killer rabbits' was reviewed. Kevin made this assignment after the class viewed the movie 'Jurassic Park' and held a discussion about the cloning of the sheep 'Dolly' the week before. Tanisha's 2.5-page story began with 'There was a knock on the door'. Her writing was clear, albeit simple, and she incorporated her best friend as the supporting character in the role of the veterinarian assisting a 'Dr Williams' with the rabbit cloning experiment. She incorrectly described one of the fundamentals of cloning: 'The scientists worked all day long trying to clone rabbits, they simply took the gene of one rabbit species and placed it into the zygote from a female rabbit'. This is incorrect since cloning typically involves replacing an entire genome, rather than a single gene as in the case of genetic engineering and gene transfer. Even if this were a simple error in word choice, nothing in the rest of the story indicated that she understood the concepts involved in cloning.

She learned in class that a zygote is used in cloning, but gave no indication that she knew it is a fertilized egg or what role it plays in cloning.

In the next paragraph, she wrote that 'the doctors were still watching over the cloned female rabbit'. Does this mean Tanisha's zygote happened to be female? Or does she not see that the zygote is the cloned offspring from the female rabbit she described earlier? Between these two statements, these foreshadowing statements appear: 'Little did they know that some of the rabbits were infected with rabies.... She watched the rabbit. She noticed slight changes. The rabbit was growing very fast and eating a great deal of food'. The rabies seem to have nothing to do with anything else in the story except for strange behaviour, and the rabbit's growth rate was never explained. After the cloned rabbit escapes, eludes the scientists, and feeds on innocent people, the story ends with the promise of a sequel when Tanisha wrote that the rabbit was captured and killed, but not before it had mated and secretly produced offspring.

It appears that she did not envision and integrate the whole set of events and was content to do the writing, which after all met the requirements for the assignment. Three things are disturbing about Tanisha's story. (1) The mechanics of her writing are nearly perfect, but her story has no semantic organization. (2) The biological concepts are fundamentally wrong, and there is no evidence within the story that she understands any of them. (3) She may have permitted herself this lack of integration by believing that there would be no accountability for her work. Kevin has read their stories but not graded and returned them. He is unlikely to penalize her for the poor application of biological concepts out of consideration of her poor background, and because evaluating work of this kind is painstaking. This leniency in the midst of praise for completing work may be the source of the belief that if one just does the work, then one will succeed.

Her astronomy exam comprised fill-in-the-blank and multiple-choice questions about apparent celestial motion. The exam did not provide a rich sense of how well she understands that topic either. She earned 81% on the test, which contained questions, e.g. 'The greatest separation of Venus from the sun as seen as an evening star is called *greatest eastern elongation*', which she answered correctly. Her teacher's ('Joe') criterion for evaluating knowledge seems to be whether a student provides an acceptable answer to his question. In observations of his classroom, his questions to his students required one-word answers which probably could have been guessed logically. It seemed unlikely that students could generate a correct statement linking the 'terms' he was teaching them.

An unfortunate set of circumstances (burning of her family's home, approaching the end of the academic year) prevented the second clinical interview with Tanisha. However, from her academic record, it is likely that her responses to questions designed to assess the meaningfulness of her learning would have revealed even weaker understanding of the concepts than Latanya provided in the second interview.

Latanya

Latanya has attended Sci High all of her three years of high school. She scored at the 51st percentile nationally on the math subsection of the CAT, and 47th percentile in science. There is no evidence of disciplinary problems with Latanya. She is friendly and outgoing, and is organizing a group of students to produce a school

newspaper. She spontaneously introduced herself the first day of observations. She sits toward the front of the class, but has been excused from class lately for activities with the endangered species education project she participates in.

The artifacts of Latanya's work in Kevin's Biology II class included her notebook (journal), her independent project for this year, and her science fiction short story on cloning. In Latanya's story, 'Growing hearts', her protagonist, Dr Smith, clones a new heart for his dying patient Charles. When there is no donor heart available, Dr Smith says a prayer for his patient and has the idea to 'replicate the DNA from a human heart cell then put that into Charles' heart, and a new heart will grow! . . . He would have to wait a week to see if the heart grow [sic]'. Using an instrument Latanya probably worked with in her summer internship in radiology, Dr Smith saw that a new heart had grown in Charles' chest and the old one had simply shrivelled and disappeared. In short, the miracle technology was 'bigger than the O. J. Simpson trial'.

Latanya's story indicates little meaningful understanding of the science behind cloning. An assumption she seems to have made is that the DNA in different organs is different. This is incorrect since all the cells of a particular organism have virtually identical genetic information. Thus, Latanya completely missed the major concept in development: that in the course of a unicellular zygote becoming multicellular, the cells differentiate by expressing different genes in the same genome. Thus, if one were able to culture a heart from DNA alone, theoretically that DNA could have come from any of Charles' own cells. Furthermore, she missed the point about cloning being the creation of a new organism asexually from a differentiated cell of the host. The cloned sheep, Dolly, developed from a single cell into a complex multicellular organism with all its organs. It would be far more difficult to get the DNA transplanted into a single cell to direct the development of a heart alone, because so much of the development of organs depends on the influence of tissue around it. These are not simply interesting details about the process that only college students should be expected to know. These are fundamentals about what genes are, what development means, and how DNA differs within and between individuals.

In her notebook there are notes about deuterostomes (a developmental term in vertebrate embryology) to meiosis (the cell division that generates sperm and eggs). Like Tanisha's notes, these appear to have been dictated in class. When Latanya was asked about the biomolecule structures in her notebook, her response to the question was correct: the molecules she had drawn and taken notes on are indeed polymers, large molecules made of repeating subunits. Sylvia stated independently that they are currently studying polymers in Chemistry II, and these students, including Latanya, are understanding it. A major gap in her knowledge about these molecules is the fact that these are the major components of all cells in all tissues in all organisms, hers included. She only saw their food value. This is probably related to lay exposure to these terms in a nutrition context, and possibly experience with the traditional lab exercise in which foods are tested for their biochemical content.

Phyllis: Where are these [biomolecules] found?
Latanya: They're found in plants and, let's see, different foods. Different carbohydrates in our foods.

This gap in understanding the importance of proteins, lipids, nucleic acids and carbohydrates in all cells' structure has been encountered often by us at the college level as well. As a check on her knowledge, she was asked what was bigger, a protein or a proton. She correctly answered that a protein is larger once she recalled that a proton is a part of the atom. Although she incorrectly stated that starch was larger than a cell nucleus, a molecule of starch had not been explicitly specified. Starch granules in plant cells are often much larger than the nucleus.

A few days prior to the second interview, Kevin had his class perform an activity that simulated natural selection by having the students use plastic utensils to 'forage'. In that activity, Latanya and her classmates each represented organisms with particular morphologies (appendages made of ether two plastic knives, spoons or forks). They were to use these appendages to gather as much food (dried corn and bean mix) into a plastic bag (the organism's stomach). After each 30s foraging session, the 'morphology' getting the most food into its stomach would reproduce most successfully (getting two offspring of the next generation). The morphology with the second most got one into the next generation, and the one with the least food got no offspring. Latanya understood that part of the exercise, but stumbled when asked what was meant by populations, species and morphology. After it appeared that she did not meaningfully understand 'populations', she was asked whether the competing populations were three different morphologies of the same species of elephant, or three different species of elephants, or three diverse species, e.g. an elephant, giraffe and monkey.

P: OK, . . . Would you say that an elephant, a giraffe and a monkey are competing for food, would that be it?, or three different kinds of elephants? or would you [she interrupted]
L: Let me see how that is . . . I think it would be three different kinds, like an elephant, a giraffe and a monkey, like that.
P: OK, so what happened when you did that activity?
L: We each had a morphology, as he called it.
P: And what's a morphology?
L: I have to think about it.
P: Well, in your own words,
L: It's another word for like a species, something like that. He just used morphology.

Latanya has an understanding of the competition in natural selection, but has not grasped that this competition occurs at the level of populations, which are groups of organisms of the same species, but that have different morphological (structural) features that either help them compete better or are disadvantageous. Kevin used the term 'populations' often, consequently she does too. But she does not have the correct concept to correspond to it, possibly because Kevin wrongly assumed they understood the distinction that he does.

Phyllis: What would you like them to think it [a population] is?
Kevin: Well, I'd like them to think of a population as this cohesive unit that behaves, almost like an individual.
P: And you're assuming they know it is one species?
K: Yeah, we talked about that, I said that a population from an ecological definition is a group of organisms from the same species that you have decided you can treat separately because there's not enough interaction with other groups around, so you can treat them separately.
P: OK, and then what do you think they think a species is?

Dimensions	*Tanisha*			*Latanya*		
GPA-Sci High	2.0			3.2		
Home High	2.9			3.7		
Planned college major	Biology			Biology		
Career Plan	Pediatrician			Pediatrician		
Social-psychological factors:						
self-esteem	excellent			excellent		
motivation	high			high		
confidence	apparently high			apparently high		
CAT %ile-						
Math	14th			51st		
Science	15th			47th		
	hers	nat'l %ile	state %ile	hers	nat'l %ile	state %ile
ACT-composite	14	8th	13th	21	58th	71st
Math	16	25th	37th	16	24th	36th
Science	14	6th	10th	19	40th	56th
Reading	13	10th	16th	26	80th	87th
English	12	7th	10th	21	59th	66th
Parents' Education	both finished high school, mom in community college			both finished high school, father a minister		
Others in Household	two middle school siblings, brothers' 3 preschool children			two preschool sisters		

Figure 1. Comparison of Tanisha and Latanya.

K: I told them, they seem to have a good concept of what a species is, because I asked them and they basically told me what I wanted to hear, which is basically a group of organisms that are reproducing together.

The distinction between species and populations was either not made explicit by Kevin because he assumed they knew it, or he did not make them accountable for the distinction. He did explain to them that morphology is the 'phenotype that results from a genotype, which can be affected by mutation'. It seems unlikely that was understood meaningfully in a single pass by the students, even the 'good' students like Latanya.

Latanya's independent project for this year was 'Does water temperature affect the breathing rate of goldfish?' It was a simple yet well-executed and reported experiment. Although her data table and graph explained the results satisfactorily, there was no mention in the introduction or discussion of why that is an important characteristic to measure.

Participant comparison

According to their Sci High teachers and principal, as well as by their own admission, both Tanisha and Latanya are highly motivated, hard-working students. Although 'Tanisha is operating from more of a deficit' according to Joan, she is curious and aggressive about learning more about science, as is Latanya. Both Sylvia and Joan intimated that Latanya's better academic record may not accurately reflect a true intellectual advantage. Sylvia said Latanya is 'on the surface more able', while Joan admitted that Latanya's advantage may be because she writes better and can express her ideas better.

Tanisha and Latanya are similar in other respects. They both have friends at Sci High and their home schools, and neither peer group discusses college and career plans except to acknowledge that they have a plan to go. When asked who their role models were, neither named one. When asked whether sports figures were role models, Tanisha cited Michael Jordan and Penny Hardaway for the way they play, but not for characteristics of their personalities that led to their success. Likewise, Latanya had no particular career role model. She looks up to her mother, as well as anyone who strives for success. Since she describes herself in similar terms as her role model (strives for success), we infer that her self-esteem is high.

> Phyllis: Do you have any role models? Anyone you look up to, want to be like?
> Latanya: ... hmm. Obviously my mother, but for other role models I have general role models. Anyone who's striving for success and getting there being humble, not by being a big shot, getting there leisurely and successfully. I do not have one person. I think, you know how some people single out one person? [For me] it's more than one person. Because your role model was influenced by another person.

Their friends' career choices are quite different from theirs. Tanisha's friends want to be veterinarian and computer engineer, and Latanya's want to be a gospel singer and an organizational psychologist. Lots of dreams were shared, but no concrete plans or perceptions of what these careers would be like were evident.

Both girls live in poor urban neighbourhoods in two-parent families with young siblings. Both have computers at home and parents who encourage their children in school, but who have not taken concrete steps to help them, e.g. by bringing them to visit colleges. Both mentioned that college will require dedication and they look forward to growing and being in a new world. Neither participant indicated on her college entrance exam inventory that she anticipates academic problems in college. Both came to Sci High for the opportunities and out of curiosity, and feel that they get more attention and guidance at Sci High. Both believe that you get what you earn when it comes to grades. Latanya puts her faith more centrally in her life than Tanisha reported. Another contrast is that Tanisha's family is in the midst of crisis from losing their home to fire and to her brother's imprisonment on a murder charge.

A negative evaluation of Latanya's and Tanisha's knowledge could be criticized for using unrealistic standards. We disagree with this notion since there is little value in producing a correct definition of a process but using fundamentally misunderstood words to do so. Even provided with an opportunity to clarify and redeem her explanation of 'population', Latanya chose the most incorrect situation. Furthermore, the weak content both participants exhibited in their cloning stories was in stark contrast with two other students' stories which provided a much stronger and more logical plot development based on correct content knowledge about the biology behind cloning. Both of these other students are high-achieving females (Asian and Caucasian) who attended two highly rated academic magnet schools in the city.

Sci High school context

Sci High was established six years ago by university scientists and a mathematician who saw the need for a special science high school but did not care to bring a politically unpopular elite school to the city. Therefore, it is a public half-day high

school for which admission is based on motivation and interest in science as measured by an interview and teacher recommendations, rather than on academic achievement as with other magnet schools in the city.

In the school profile is their mission statement:

> Sci High believes that both high-achieving students and students who in their earlier years were interested [but lost that interest] in science and math can have their interest recaptured by a new academic focus. Activity-based learning, using apparatus and discovery methods leads to the natural discovery of concepts. Working on group and individual research projects brings the satisfaction of 'doing' science. Sci High is a professionally equipped, resource-based school. We aim to benefit our students by increasing their earned self-esteem and confidence and, therefore, their life options. The economic benefits to our city are clear.

In Sci High's 'What we are and what we are not' flyer, hard work and good behaviour is emphasized as necessary to remain enrolled in the school. The overall tone of the page is captured in this line from one of the items. 'We do not tolerate tardiness, frequent unexcused absences and a casual attitude toward work, either inside the class or at home regarding assignments.'

Students in all the classes observed were participating in the activities, but how cognitively engaged they were was not apparent. Activities or lines of questioning that could externalize students' conceptual frameworks were not observed. Most of the students' questions were procedural ('How much of this should I add?') or pleas for relevance ('Why is blindness so hard to cure?'). The latter-type questions were answered satisfactorily but perhaps not effectively from a pedagogical standpoint. Two students in Joe's class completing their exam review sheet said they are reluctant to ask him a question in small groups because his answer is usually longer than they want. Joe is very knowledgeable and has ready answers, however, these answers do not invite students into an inquiry. Joe might correctly say that most students would decline such an invitation.

Ideas were a major commodity in Kevin's classroom, but they were primarily his own. His enthusiasm and mastery of his content is palpable, and quite understandable to an observer who is also an enthusiastic biologist, teacher and verbal learner. However, experience in teaching biology to college freshmen suggests that students cannot appreciate the elegance of the models and experiments in the same way he can. He is conscious of the varied needs of his students and leaves his explanation at a high level for the sake of his magnet high school students, then only makes the class accountable for the gist of the content he presented. Some Sci High students who attend the best-regarded academic magnet indeed can grasp these high-level abstract concepts, but his idea-based classroom leaves the others like Latanya and Tanisha with merely a new set of vocabulary words to use.

More evidence of conversion by the Sci High teachers to a more constructivist/student-centred classroom (American Association for the Advancement of Science 1993, National Research Council 1996) was expected. Teachers' awareness of students' prior knowledge, potential misconceptions and relevance of the information to their lives was also not evident. It seemed that all three teachers assumed that their students heard, cared about and internalized everything said. Although the teaching was satisfactory in each classroom, it is not clear that the learning reflected that.

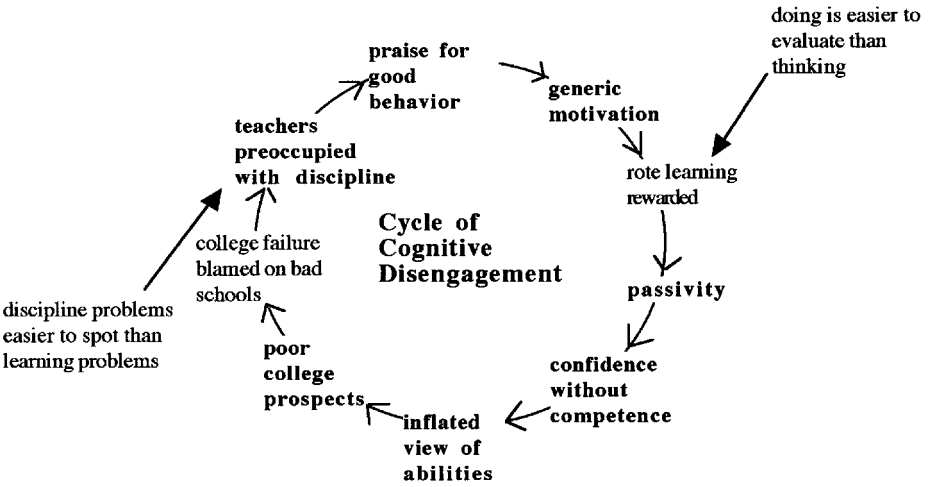

Figure 2. Cycle of cognitive disengagement. The steps in bold indicate themes that emerged in this study.

Emerging themes

Once serious gaps and errors were found in Latanya's and Tanisha's conceptual frameworks for recently studied topics, analysis turned to a study of the learning environment that permits these problems to persist. The following themes emerged over the course of the study in approximately the same order as they are presented below. Since they seem to have a logical, serial, potentially causal relationship, we propose relationships among them in figure 2: the cycle of cognitive disengagement. In this section, direct quotes are offered in order to preserve and convey the actual conversation as much as possible. Where they are long they either bridge two themes (as in Nia's) or convey a thoughtful consideration of the issue (as in Eleanor's).

Attending to behaviour over learning

It was noticed early that behavioural and academic discipline gets more attention than meaningful learning at Sci High. On each student's Sci High grade report card, the student's discipline grades appear prominently in the centre of the page, ahead of their 'evidence of learning' grades which are recorded at the bottom of the page. Good behaviour and grades are frequently praised at Sci High: students on the honour roll are recognized with a certificate at an all-school meeting, and students with the highest behaviour ratings were treated to a picnic. Is one reward perceived to be more valuable than the other?

The superintendent's motto makes his priorities clear: 'Respect for life, property and learning', in that order. Perhaps the superintendent believes that taking care of life and property is also a prerequisite for learning. These observations indicate that discipline is thought to be a prerequisite to learning. Is it not possible that the converse could be true, that a satisfying experience in meaningful learning can beget academic discipline, as is the case for Nia (see below)?

So learning is last, just like in the motto and the report card. Learning is what gets done if we have the cooperation of the students. But Tanisha and Latanya comply with the behaviour and homework expectations at Sci High. Is rich content knowledge and development of critical thinking skills an automatic outcome? This was not our observation.

Lack of academic habits in the presence of a work ethic

A frequently heard comment from Sci High's principal and teachers is that their students lack 'academic habits'. They say it is hard to get them to do homework and get tutoring help when they need it. This was not the case with either Tanisha or Latanya. Both have learned to work with their friends to complete their assignments. Both readily berate their peers for getting what they deserve when they do not do their homework. Are these the academic habits they are being encouraged to develop? If such habits are necessary and sufficient for meaningful learning, then Latanya and Tanisha should be learning. Tanisha believes school and life is like that: do what you are told and you can succeed. 'I'll take the necessary steps', she says, as if those steps are concrete and as readily accessed as her track and field competitions. It appears that since their knowledge about the topics discussed in their classes is not robust, then the 'necessary steps' are not sufficient. Whether it is from their families, home schools or Sci High, both have got the message that schoolwork is important. Both have a strong work ethic.

So what is the difference between 'the lack of academic habits' and what the students are dutifully doing each night? What is missing is cognitive engagement, which is avoidable when assignments can be completed without significant cognitive effort. In Kevin's case, the assignments are very carefully planned, but students are not held accountable for the content of them since assignments had not been rigorously graded. This makes the point of his carefully constructing them moot.

The rhetoric in science education today is that hands-on is the way to teach science. This is certainly an improvement over the old lecture/memorize tradition, but is no guarantee that learning occurs. All of the teachers observed employed hands-on activities, but none pressed their students for cognitive engagement while doing it. They may think, like Eleanor, that hands-on activities measure minds-on engagement, although upon reflecting on it, Eleanor recognized that an activity-based curriculum may not be sufficient on its own to spur learning.

Phyllis:	Do you think there's a lot of minds-on learning while they're doing their hands-on work?
Eleanor:	Well, I do. I think that if 'minds-on' means intellectually engaged, then I think so. Although it's difficult to measure, because if you try to talk with them about it... I don't know if it's because it's difficult to express, or because they really haven't been thinking.
P:	Which one do you think it is?
E:	I guess... my hopefulness is probably interfering here in this judgment.

Thus, a theme that emerged is that although Latanya and Tanisha have developed a discipline of doing their schoolwork, and their teachers provide abundant hands-on experiences, there is no evidence that these have led automatically to robust learning about the topics.

Cognitive passivity

In spite of their conscientious efforts, teachers at Sci High feel frustrated with their students' poor academic background and thinking skills. However, their awareness of their students' academic shortcomings makes them better poised than the home schools to do something about it. It seemed that it was hard for Kevin and Joe to get their students to respond in spite of their invitations. Eleanor said that a new teacher came to her in tears for the better part of this year because her freshman students were resisting the pressure she was placing on them to interact, collaborate and engage in her Algebra class whose design Eleanor gushed about.

Eleanor remarked on the passivity she has encountered with regard to Sci High's students' willingness to think critically.

Phyllis:	What about their thinking skills?...
Eleanor:	They're used to just fact recall, and they're very resistant to analysis and interpretation, prediction and evaluation... but they're certainly capable of doing it... I find their capacity to analyse is fine. Their willingness? What stands in their way is their passivity. They're incredibly passive. I don't know if all adolescents all across America are now, but I know our kids are.
P:	How do you get them to engage? In a conversation, or in minds-on...
E:	Yeah, on an academic subject? It's tough.
P:	Do you think anyone (here succeeds)?
E:	I think intermittently yes.

Teachers' attention to cognitive engagement

When asked about how they know their students understand a concept, Sci High Biology teachers 'Joan', 'Joe' and 'Kevin' all stated that they ask questions in class. Although Joan's class was not observed, her uninflated evaluation of her students' ability indicates that she may be uncovering their real understanding. She cited an example from that day in which their class activity was about coral reefs. The students thought she was being unfair to expect them to know whether coral are plants or animals. We agree with Joan that this is more fundamental than many other 'facts' about coral reefs her students recalled.

In contrast, Joe's questions were frequently answerable by rote recall. He was appalled that his students did not remember from the year before that an ulna was an arm bone, a lack that troubles us less. Kevin also believes he understands what his students know because he constantly asks questions in the course of his class. After an interview with Latanya cast doubt about this, Kevin was asked whether his students know what a species and a population are. He responded yes, because he 'told them' and they 'talked about it'. In the classroom observations, his students were not witnessed talking about the biology content much.

One reason it is difficult for a teacher to get all students cognitively engaged is because it requires placing uncomfortable pressure on the students to participate. Most teachers are unwilling to put their students on the spot out of consideration of the shy ones. They are willing to permit such passivity, and thus only interact with those who want to be interacted with. Eleanor was asked whether teachers should pressure all their students to interact to prove they are engaged cognitively.

Phyllis: Is it important to get all the kids in a class to participate?
Eleanor: I think it's *very* important.
P: Even if they want to be passive?
E: Yeah.

Teacher tolerance of students' cognitive passivity and their belief that doing begets learning mutually reinforce each other. The failure to make students accountable for the learning they believe they have achieved may be responsible for students' inflated sense of their abilities: confidence without competence.

Generic motivation – confidence with competence

The motivational speakers who do the school circuit and the inspirational banners hung around the school grounds may be effective in raising confidence and elevating dreams, but their messages are generic and offer no concrete suggestions for setting subgoals. Both Tanisha and Latanya are clearly motivated. Tanisha especially seems affected by these 'speakers who say these quotes and stuff'. However, among the motivational speakers she has heard, she respects the 'real people' who have done something with their lives over the 'generic motivators'.

Generic motivation, as identified above, leads to what Eleanor calls 'confidence without competence'. Over the years, Eleanor has witnessed teachers at other schools issue abundant but generic motivation of their students in the absence of real teaching and learning. This has instilled an unjustified confidence in students, which has appalled Eleanor.

Eleanor: It's the myth and ceremony about school. There's no *content there*. Most of the schools in the city are not schools. They are places where adults and children meet every day, we feed the children and pay the adults. That's sort of a benign arrangement, nobody being directly hurt.
Phyllis: Do you think most schools are like that?
E: 90% of them. It's appalling, it's a sin. It's a word I don't use very often. I'm defining a sin as an act of self-interest without regard for the whole... [The teachers] blame the kids [for their not being able to teach them], 'they come from broken homes', so [their teachers] tell them they can be somebody. I don't want [them] to do that, I just want [them] to teach them every day from the beginning of the bell to the end of the bell....

Although Joan and others intimated that most of their students overestimate their knowledge and ability, Eleanor is the only one who may understand that generic motivation contributes to it. She is especially concerned about how this affects their ability to develop life skills, not just science knowledge.

Eleanor: Everything we're learning here is not so much what you remember about the medulla oblongata, but rather how much you learn to be in control of your own life, and how much you've learned to make good decisions, learned about how to solve a problem. All of this stuff is life skills, and the ability to think well, and to participate in the community. I don't think we're training everybody to be mayor, but we are trying to train people to be competent and confident... I want the confidence based on competence... Let me say this another way. I feel as though giving them confidence based on their competence is extremely difficult, that they have a false sense of confidence.
P: Do you think they have that here?

E: Well, it gets knocked down here. Many of them come here having been star pupils. And I think other teachers are saying, 'you know we want them to feel good about themselves'. [Never mind that] they aren't working hard to teach them, but they're telling them what big kids they are and you can be somebody. You can only be somebody if you have some skills. Those you have to develop, you aren't born with them. . . .

P: Do you think Tanisha and Latanya have the ability to realize their dream of being paediatricians?

E: I don't.

P: Neither of them?

E: No, I doubt it.

Prospects for college success

Eleanor's grim assessment of their potential is in line with the statistics published by Premed U's premedical office. Premed U produces more African–American medical students than any other institution nationally. In the year the statistics were compiled, no Premed U student with Tanisha's high school GPA and college entrance exam scores was accepted to medical school, and only 27% of students having Latanya's record were accepted. Both Tanisha and Latanya believe they will be paediatricians if they put their minds to it and work hard. Eleanor, Joe and Joan believe they both can graduate from college, although Joan was a bit more optimistic about their prospects of becoming paediatricians. Even then it hinged on whether they had the intellectual wherewithal to rise to the cognitive challenge of college that they were beginning to be presented with at Sci High.

Phyllis: How will they do in college? They both want to be pediatricians.

Joan: I think if they keep up their enthusiasm, they'll be fine. Tanisha is working with more of a deficit, but has enthusiasm that I hope will make up for that. Both probably overestimate their knowledge in science, and when they go into college it's going to be a tough awakening to see that they may not be up to the level that they think they are.

P: Where did they get that?

J: I don't know where they got it, but a lot of students I teach feel like they are doing fine, and they're surprised when I evaluate their work or their knowledge to be not acceptable, because they think that it is.

Nia is an African–American female biology student at Liberal Arts U. She is the product of a similar socioeconomic upbringing in historically black schools, except that they were parochial schools in the city. Nia is a very bright woman. She has earned a 3.6 grade point average on a 4.0 scale, is on full academic scholarship, and is by all accounts a meaningful learner. By most measures she is likely to realize her dream of becoming a paediatrician. What's different about her? Was she like Tanisha and Latanya when in high school? Quite possibly. Nia was almost as much in the dark about college as they are, and she was equally optimistic about her prospects for academic success.

Phyllis: Well I keep thinking about these girls I'm interviewing. They have no idea what college is like. They don't really know how to get an idea. And you didn't know either?

Nia: Well in high school we had academic counselors. They kind of gave you a feel for what it was like. They told you it's going to be difficult, you can't really cram all the time.

P: Other than that message, you never sat in a college classroom?

N: [Once in a calculus class, and once with a friend at another school.]

P: Was the information in the class intimidating?
N: No...

In Nia's case, her fearlessness about college was justified. How are Nia and her successful academic sisters different from Tanisha, Latanya, and other young African–American classmates of Nia's who have struggled? The difference is that Nia learned early in college what it feels like to really understand something.

Phyllis: But I think you are very different academically from [your less able classmate] 'Keisha'. If I sat down with you to have a scientific conversation, we could have a pretty deep discussion. There were girls who would study, study, put the time in, and still not get it
Nia: It's training
P: What's different?
N: I know how to study.
P: How did you learn?
N: It's about repetition, and it's like something kind of clicks.
P: Do you get a rush when...
N: [big nod yes]... *And it feels GOOD too* [her emphasis]. It feels good when you go and take a test and you KNOW that stuff.
P: So there's a rush. What if someone has never had that feeling?
N: Then they don't know how to study until they get that feeling, because they think that there's no feeling, they don't think there's that rush.
P: Do you think that everybody should be able to get that feeling?
N: Yes.
P: So you don't think it's something that is physiologically [different among people].
N: No.
P: So you think everyone is capable...
N: Of the rush.
P: So someone else felt the rush, that's good to know... But what about, and you probably study with people like this, who read it, they go through the motions, they memorize stuff, but they just haven't internalized, you know what I'm saying, it's only on the...
N: The surface.
P: ... But what if you've never known that feeling? How do you teach someone what that feels like. They may never have done it and then they get to college, and it's like I know I didn't really know anything until I got to college.
N: Me too! I feel the *same way* [her emphasis]. I feel like I never learned anything until I got to college, and then you *learned* stuff [her emphasis]. I don't know what it is. I think it's just basic stuff. I don't even remember anything from high school. Maybe I remember but just can't think of it now. But from my first semester [in college... I remember everything].

Metacognition and cognitive reward

Nia not only is metacognitively aware, she even experiences a visceral reward for her intentional learning efforts. This 'rush' was unknown to her in high school. She is aware that her transition to college marked a clear boundary in her cognitive development, from a time in which she remembered 'nothing', to one in which she remembers much of what she learns meaningfully (this was verified in the other project being conducted about her knowledge of a topic she learned the previous year).

Nia believes it is possible for everyone to achieve this cognitive reward. Although she is only a few years older than Tanisha and Latanya, there seems to be a considerable gap between their abilities to learn. The goal of Nia's learning

is understanding, whereas the goal for Tanisha's learning is passing and Latanya's learning is excelling. Latanya also is more likely to look for ways to apply information in other settings, a desirable metacognitive habit. However, neither seemed to have a goal of intentionally learning. Scholars who seek to apply findings of cognitive science to education have observed that Intentional Learning is development (Bereiter and Scardamalia 1989). Most of us do not develop this ability spontaneously until adulthood.

> These findings add up to the view that children see learning as an *activity*, whereas sophisticated adults see it as a *goal*...
> Learning itself, however, is not something they conceive as an intentional pursuit; they see it as a natural consequence of carrying out appropriate learning activities.

Teachers at the schools seem to have the same view of learning. Although Tanisha and Latanya are older than the children described in the Intentional Learning studies, they are somewhat closer to this learning description than they are to Nia's. Twelve years of schooling teaches students how to cope with school's expectations. Without a recognition of this, even the best teachers continue to issue schoolwork with the belief that students will learn from it by simply doing it. 'It is probably safe to surmise that many teachers regard school learning as a natural result of learning activities and, thus, do not treat it as problematic' (Bereiter and Scardamalia 1989: 372). If indeed 'schoolwork goals provide a handy and satisfying substitute for such elusive learning goals' (Bereiter and Scardamalia 1989: 379), then what is needed to counter it? Without rigorous accountability for learning, all learning degenerates into schoolwork.

> Regardless of the best-intended, theory-driven interventions employed to promote meaningful learning, students could find a way around learning and reduce it to schoolwork. They seem to be quite adept at these coping skills. They have developed systems for avoiding the great cognitive effort that true learning requires.

Tanisha and Latanya are no exception. They too are susceptible to developing coping skills to avoid the hard cognitive work of meaningful learning. They know how to do 'school', but they have not been modelled genuine academic habits that are required for an 'education'. They have not learned how to learn.

Both students showed signs that they did not know when they did not know. They had not developed significant self-monitoring habits, and they instead relied on their teachers to feedback whether they have learned the information.

Phyllis:	How do you know when you know something? How do you know when you've got it?
Tanisha:	When you can do it without help, if it's in your head. I go by the tests. If you can do it on the tests...
P:	But how do you know before you go into the test? How do you know when your studying its finished?
T:	Once I study, well, I just close the book, I concentrate, then once I can just answer right out of my head what I know is going to be on the test, I think I know it.

Latanya did show evidence of some metacognitive ability. She feels it is important to retain information from her classes and tends to relate things she is learning with things she has learned previously. She is aware that she tries to link new information to her prior knowledge, and knows that this is not a habit most

students have. They prefer to leave it inert. Her spontaneous metacognitive ability is a desirable quality that was not witnessed with Tanisha.

Phyllis: What do you think the key to success at this school is?
Latanya: Basically I think it's self-determination, and retaining the information for later use.
P: Like later in the year, or later in life?
L: Later in life! Because if . . . I learned this in algebra II about [something else] And they think you're a genius.
P: And are you?
L: I always though of a genius as a person who was really really smart, but I [now] think a genius is a person who's well-rounded, who has common sense as well as education/academic [sense] . . . You have to learn from real situations. It's not always in the books . . .
P: So it looks like you actively try to link things you learn in one place to other places, do you think you do that?
L: Yeah, I think I was with [the endangered species club], . . . and I remembered I learned that in chemistry and it made me understand things clearly.
P: Do you think most people look for those connections?
L: I think most people . . . they don't. They say, well I learned this in 4th grade, that's when it's gonna stay. I learned this in world history, no need to learn it in 11th grade, because world history was last year.

Before the final interview with Eleanor, a shortage of metacognitive awareness with both girls had been observed. Eleanor unwillingly confirmed it by spontaneously bringing it up while discussing assessment. When asked about how teachers can know their students have learned, she considered interviews valuable not only for this purpose, but as a way to assess metacognition.

Eleanor: Well we will do an exit interview [with our seniors], but it would be cumbersome [to do assessment] with individuals. For example when I taught reading I never gave book reports, we had book conferences. And they loved it, they had one-on-one time. It was an opportunity, you know. As a teacher you can find out a lot by interviewing them . . . I suppose you could do that with Science and Math. It seems to me the only way you can tell what a kid is thinking is by talking to them about thinking. And see if they understand. There's this whole new field of metacognition, which I think I'd sort of like to do my PhD in because I'm so interested in it as a field. I want to know how much kids are aware of their thinking themselves, how self-analytical they are, and self-correcting. Is that something that kids can do, or is there sort of a maturation link?

Conclusion and recommendations

It should be stated that a subset of the problems with meaningful learning described has been observed by us among biology students of all cultural and socioeconomic backgrounds. Thus the findings do not apply singly to African–American females or to urban public schools.

The original goal of this study was to answer the question of how the home high schools of these young women influence how they learn science at Sci High. Visits to classrooms at the three schools and study of Tanisha's and Latanya's knowledge and attitudes indicated that 'successful' students like Tanisha and Latanya in both places are improving their schooling skills, but not necessarily their education. While the resources are plentiful, the teacher is the best in the

state, the school has pride and the students are well-behaved, nothing indicates that what goes on in the Sci High or Latanya's 'Magnet High ' biology classroom invites more cognitive engagement than at Tanisha's 'Neighbourhood High'. Is cognitive engagement a prerequisite for learning? The clinical interview with Latanya revealed a fundamental lack of understanding of core concepts. Neither Kevin, nor Sci High, nor Magnet High is directly to blame. The lack is one result of a complex set of school/cultural factors.

First year students at Premed U who were graduates of Magnet High school and others like it often said they spent hours doing something called 'reading, homework and studying'. This did not necessarily lead to intentional, meaningful learning needed to succeed in the challenging introductory biology course. It has been found that successful students who spend the same amount of time reading their textbooks do so differently than their less successful classmates. As they read they transform the information and intentionally make it more meaningful for themselves (Wandersee 1988). Among the introductory biology students at Premed U, the aggressive ones who were confident enough to seek help could sometimes learn how to study meaningfully after only two failed exams. But for the majority it took longer, often until it was too late and they had to change their career plans. The outlook was even more bleak for graduates of neighbourhood high schools like Tanisha's whose few representatives at that university were so passive and disconnected from their professors (in spite of outreach) that they did not know how to seek help.

What causes this lack of understanding about learning? We propose the following to illustrate how the themes that emerged in this study feed into a cycle of cognitive disengagement that perpetuates failure to learn meaningfully and develop metacognitively. The 'feeder bands' in the hurricane-like spiral indicate the challenges of pedagogy that aggravate the condition: the fact that evaluation of behaviour and written activities are easier to evaluate than invisible learning structures. The hurricane in this analogical graphic is also apt because a 'satellite view' provided by the model more readily facilitates understanding and discussion of the problem. It also represents the dangerous lack of awareness those at the 'eye' of the storm have of the circumstances surrounding them.

In some schools, some of these factors are more influential than others, however, the model was constructed in consideration of our findings at all three schools. Since neither peer nor teacher influence was directly cited by the participants, we conclude that the problem exists on a higher level than that, perhaps at the level of the community.

Many theory-driven interventions touted by the reform movement have been applied in all the science classrooms visited (hands-on, inquiry-based learning, cooperative group work, technology), but none has been able to break the cycle in a way that could be observed. There may be promise in improving intentional and metalearning by a cooperative learning strategy called Reciprocal Teaching (Brown and Palincsar 1989). Reciprocal teaching has been successful in raising the questioning ability, reading skills and critical thinking in various kinds of students, including 'at-risk'. One requirement for its success is its conscientious implementation by the teacher. A poorly-informed or half-hearted attempt to implement this intervention will not meet with the same success. Many pedagogical findings based on cognitive psychology, from multiple intelligence to concept mapping, have similarly failed to apply widely when the distance between theory and practice

becomes too great for all the stakeholders' accountability to be rigorously checked, and the interventions degenerate to 'schoolwork'.

Another way in which theory and practice are still distant is in the proposal of a single coherent theory of science learning that accounts for cognitive, social, affective and ontological features of the learner. In spite of all the attention in the science education literature to affective issues, only recently has such a multi-dimensional framework been proposed for looking at the findings in science education (Treagust *et al*. 1997). It represents an interest in consolidating and acknowledging how these dimensions interact to effect conceptual change. Treagust *et al*. believe that failure to develop all the dimensions of the learner will prevent conceptual change in any of them. They explain the need for an interpretive framework in these terms:

> Most empirical studies researching conceptual change do not overtly consider the multiple influences on changes in students' conceptual understanding, rather they document the changes in content knowledge as elicited by probes like tests, worksheets and interviews that concentrate on what the student knows. Considering changes to content knowledge as elicited by tests and their like is an important aspect of conceptual change; however, it must be acknowledged that surface evaluations of learning often overlook the epistemological, ontological, and social/affective influences that are essential for the progress of conceptual change.

This at least shows that theory-driven science educators are approaching the research on classroom practice. If researchers in science education are only just now considering motivational and affective dimensions in their theories about cognition, then their work is still a long way from influencing how Tanisha and Latanya learn. But this does not mean that students will not find it within themselves as Nia did.

> Phyllis: I asked [Nia] when she figured [learning] out. She said that high school was a blur, and the whole thing blew open [for her] in college... She'll be a pediatrician.
>
> Eleanor: I think of the two, it might happen with Latanya. But I feel she is more mature intellectually and personally. Tanisha has come a long way, and she may keep on. Who knows if the zenith is ahead.

References

American Association for the Advancement of Science (1993) *Benchmarks for Science Literacy* (New York: Oxford University Press).

Bereiter, C. and Scardamalia, M. (1989) Intentional learning as a goal of instruction. In L. B. Resnick (ed.), *Knowing, Learning and Instruction: Essays in Honor of Robert Glaser* (Hillsdale, NJ: Lawrence Erlbaum), 361–392.

Brown, A. L. and Palincsar, A. S. (1989) Guided, cooperative learning and individual knowledge acquisition. In L. B. Resnick (ed.), *Knowing, learning and Instruction: Essays in Honor of Robert Glaser* (Hillsdale, NJ: Lawrence Erlbaum), 393–451.

Fensham, P., Gunstone, R. and White, R. (eds) (1994) *The Content of Science: A Constructivist Approach to its Teaching and Learning* (Washington DC: Falmer Press).

Lincoln, Y. S. and Guba, E. G. (1985) *Naturalistic Inquiry* (Newbury Park, CA: Sage).

National Research Council (1996) *National Science Education Standards* (Washington DC: National Academy Press).

Novak, J. D. and Gowin, D. B. (1984) *Learning How to Learn* (New York: Cambridge University Press).

Patton, M. Q. (1990) *Qualitative Evaluation and Research Methods*, 2nd edn (Thousand Oaks, CA: Sage).

Posner, G., Strike, K., Hewson, P. and Gertzog, W. (1982) Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education,* **66**, 211–227.

Treagust, D. F., Venville, G., Harrison, A. G. and Tyson, L. (1997) A multi-dimensional interpretive framework for understanding conceptual change. Paper presented at the National Association for Research in Science Teaching, Oakbrook, IL, USA.

Wandersee, J. H. (1988) Ways students read text. *Journal of Research in Science Teaching,* **25**, 69–84.

Yin, R. K. (1994) *Case Study Research: Design and Methods*; 2nd edn, Vol. 5 (Thousand Oaks, CA: Sage).