Paper Presented at the AARE Annual Conference, Brisbane, 2002
Australian Association for Research in Education

TSU02499

A Preservice Science Teacher's Pedagogical Content Knowledge (PCK): The Story of Linda

Chi-Yan Tsui and David F. Treagust

Curtin University of Technology

Paper presented at the Australian Association for Research in Education (AARE) Conference Brisbane, Queensland, Australia, 1-5 December 2002

Abstract

This paper explores teachers' pedagogical content knowledge (PCK) through the story of Linda, a preservice science teacher, who participated in this study while she taught genetics in a Year 10 classroom during her practice teaching. The study utilised a case-based research methodology with multiple sources of data that included interviews, observations, and information and communication technologies (ICT). Linda developed her PCK while teaching genetics and trying to use *BioLogica*, an interactive multimedia program. Although Linda did not have a strong content knowledge of genetics, she was able to expand it in response to students' learning demands. She also improved her pedagogical knowledge through reflection upon her teaching practice despite difficulties she encountered. Classroom observations showed that students had been highly motivated and actively engaged in their learning during Linda's teaching. Her expectations and reflections in the interviews corroborated with our view that she had undergone change in her conception of teaching genetics and substantially improved her PCK. The findings have implications for improving preservice science teacher education. It may be useful to highlight preservice teachers' PCK for teaching in their domain-specific areas and to introduce the functions of multiple representations in ICT learning environments for improving classroom use of technology.

Introduction

Over the past two decades, researchers in Australia, New Zealand, the UK and the USA have unanimously found that genetics remains linguistically and conceptually difficult to teach and learn in secondary schools . As such, preservice teachers are likely to find genetics even more difficult to teach.

The theoretical framework in this case study utilised the multidimensional conceptual change model (CCM) for interpreting learning, other perspectives are also used, in particular, the analysis used interpretation of the classroom discourse that incorporated computational perspectives , social constructivist ideas and sociolinguistic views . Further, the research literature on teacher knowledge was also an important source of reference for the theoretical framework.

Paper Presented at the AARE Annual Conference, Brisbane, 2002
Australian Association for Research in Education

Since the 1980s, Shulman's model of teacher knowledge incorporating the construct of pedagogical content knowledge (PCK) has had an important impact on teacher education. Shulman defined PCK as "that amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding" (p. 8) and he also highlighted teachers' representation of content knowledge in teaching as follows:

> It represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organised, represented, and adapted to the diverse interests and abilities of learners and presented for instruction. (p. 8)

Recent researchers have reconceptualized Shulman's classical definition of PCK in light of the findings of new studies. For example, on the basis of a review of literature, particularly that of Grossman's work, Putnam and Borko discuss PCK in the following four aspects:

a. overarching conception of teaching a subject;
b. knowledge of instructional strategies and representations;
c. knowledge of students' understandings, thinking, and learning in a subject; and
d. knowledge of curriculum and curricular materials."(p. 1233).

More recently, Loughran, Milroy, Berry, Gunstone, and Mulhall reconceptualise PCK as being "the knowledge that a teacher uses to provide teaching situations that help learners to make sense of particular science content."(p. 289). Despite some recent studies about the preservice teachers' learning to use technology in teaching , studies about teachers' PCK using technology in teaching science remain a largely uncharted area of research.

Research Method

As one of the case studies of a larger project, this study utilised an interpretive research approach with case-based design . The data collection, analysis and interpretation followed the tradition of case study methodology but some methods specific to this case study were used.

The original objective of this case study was to find out how preservice teachers understand *BioLogica* , an interactive multimedia program, and how they plan to use it in their teaching. In response to the first author's call for participation, a presevice teacher, Linda Bell (pseudonym), volunteered to participate because she said she was interested in the *BioLogica* program. Linda tried out the software and later invited the first author to School B where she had her practice teaching.

Although the research in School B had the full support of the school and Linda's university, the tight time constraints, and the tensions working in a preservice teacher's field experience school made data collection difficult. We highlight here the teacher's voice using contextualised narratives in terms of vignettes in reporting the research findings. A vignette is a "vivid portrayal of the conduct of an event of every day life, in which the sights and sounds of what was being said and done are described in the natural sequence of their occurrence in real time." . This is in keeping with an increasingly important trend of reporting research about teaching and teacher education in Australia .

Paper Presented at the AARE Annual Conference, Brisbane, 2002
Australian Association for Research in Education

Research Question

Based on the emergent design in case study methodology , this case study was informed by the prelimnary findings of the previous case study in School A that immediately preceded this case study. In this paper, we will discuss one of the specific questions which guided this case study:

How does Linda, a preservice teacher, develop her pedagogical content knowledge (PCK) when she teaches genetics with *BioLogica* that features multiple representations ?

Linda and School B

Linda, born and educated in Western Australia, was a full-time student teacher enrolled in a postgraduate diploma of teaching in one university in Western Australia during this case study. While trying out the *BioLogica* and the online tests, it happened that she was to teach genetics in Year 10 science in School B as her next field experience in School B. Linda invited the first author to School B to observe her lessons and support her in using *BioLogica* in teaching as part of the research.

School B, a government co-educational senior high school, was located in a suburb near a national forest park about 25 km from the Perth city centre. Established in the earlier 1980s and recently managed by a strong leadership team, School B p**rovided a caring learning environment that fostered excellence in all areas and conducted quality programs across the curriculum with emphasis on technology in teaching. However, as Linda told the first author, the science department had yet to integrate technology into teaching and learning. Eventually, all** 28 Year 10 students (11 boys and 17 girls) taught by Linda during her practice teaching participated in the research with their parents' consent. These students were aged 14 or 15 at the time of the research. Most of these students have English as their first language.

In 2001, Linda graduated from her university with good results and has been teaching in a country senior high school in Western Australia since the beginning of 2002. Recently, she e-mailed the first author that she found teaching challenging but rewarding and in particular, she enjoyed teaching biology and human biology.

Data Collection

The data collection in this case study took place in two phases. In the first phase, the first author worked with Linda while she was trying out the software in May 2001 whereas the second phase of data collection took place in School B where she had her field experience.

In the first phase, Linda visited our Science and Mathematics Education Centre (SMEC) once or twice a week in May 2001 to try out the *BioLogica* software and the online material and samples of online tests on genetics reasoning . She discussed with the first author in meetings or via e-mail communications about the educational potential of the interactive program and talked about how she would plan to use the program in her teaching. As she tried out three *BioLogica* activities "Introduction", "Rules" and "Mutations", the analysis of the log files that tracked her interactions with the *BioLogica* program gave the first author feedback concerning her conceptions of genetics and how she used the program.

The second phase took place in School B where she had her field experience. In School B, Linda prepared, taught and reflected upon her teaching and learning of genetics, and tried to teach with *BioLogica*. The first author observed six of Linda's ten lessons generating field-notes and reflective journals of each lesson. Four lessons were audio-taped, two lesson

Paper Presented at the AARE Annual Conference, Brisbane, 2002
Australian Association for Research in Education

video-taped and they were fully transcribed verbatim. Besides collecting some documents in School B relevant to Linda's teaching, the first author interviewed Linda before and after the 3-week of teaching and had a meeting with her for "member checking" one month later. We also shared some of our reflective journals and discussed the classroom teaching via e-mail communications throughout and right after her field experience.

Due to constraints imposed on the field experience of a preservice teacher and the tensions of busy school life, it was not possible to collect some sources of data as initially planned, especially data about student learning outcomes. For moral and ethical considerations, the first author made Linda's interests as the highest priority while collecting data. Further, the first author tried to minimise the researcher's intrusion in the classroom life and to respect the wishes of Linda, her supervisor teacher and students of the school.

Data Analysis, Interpretation and Assertions

As discussed earlier in this paper, the major focus was on a special type of PCK of Linda when she tried to teach a conceptually difficult topic genetics with technology. While Linda was grappling with her knowledge in preparing and teaching genetics, a topic which she did not know well, she endeavoured to organise and use ICT in her teaching in a school where science teachers did not have such experiences in teaching. In so doing, Linda had to make the best use of her personal knowledge and what she had learnt from her university studies to achieve her planned goals.

PCK is a complex construct. According to Gess-Newsome , PCK has its sources from three major categories of teacher knowledge identified by Shulman , namely, subject matter (content) knowledge, pedagogical knowledge and contextual knowledge. To illustrate how Linda developed these components of her PCK, we use four vignettes here to report the findings. Each vignette is entitled with a direct quote from Linda's voice concerning one aspect of PCK. Shulman's terminology will be mentioned where necessary to link the interpretation to research literature. Finally a section on PCK will sum up the findings.

First Vignette: "I think it's a difficult subject"

On 2 May 2001, having confirmed she would participate in the research, Linda came to see the first author in our education centre to try out the *BioLogica* activities and the online tests. This meeting marked the beginning of Linda's learning to teach genetics.

In a brief conversation, Linda told the first author that she was very interested in genetics but her science degree did not include a formal course on genetics. Before she started to use the *BioLogica* program, she helped in trying out the first of several samples of the online pretests on genetics reasoning which would be used by students in the research. In an open-ended question in the pretest she did on that day, she wrote, "I have not taught genetics, but I am interested in learning more about genetics and teaching it in the future." Then, as she had to hurry back to her university for some lectures, she promised to send the first author feedback by e-mail later that week.

On the following day she e-mailed the first author as follows:

> I think it [*BioLogica*] is a great tool. I like how the student can work at their own pace using this application. A few comments. I think students should be encouraged to take notes while using this application, by doing this the students will feel more confident when answering the questions. The application relies a lot on memorising what you have just read/learnt from the last pages. I also think that if the program had sounds like "well done" "that's correct" "your moving along great" etc. this kind of

Paper Presented at the AARE Annual Conference, Brisbane, 2002
Australian Association for Research in Education

> motivating and encouraging reinforcement would be beneficial, the students really need that reinforcement. I had no problems logging on to BiologicaOz [website with online material], I will try the next quiz on Friday. I hope my comments are helpful.
>
> (Miss Linda Bell/ E-mail /3 May 2001)

As can be seen in Linda's e-mail about her first impression of *BioLogica*, she already identified *flexibility,* one of the three salient features of *BioLogica,* as did most teachers and students in other case schools . She appeared to think about how computer-based learning could motivate learners within a behaviourist perspective (i.e., related to extrinsic feedback) but she actually thought of intrinsic motivations first identified in students of School A. In first interview when the first author asked her about her beliefs in using technology in teaching and learning of science, she said:

> I think it's vital. In these days kids seem to know everything about computers and they [computers] are in our lives anyway so they need to know how to use them. They are fun and kids like to do fun things. They tend to learn more.
>
> (Miss Linda Bell/First Interview/11 June 2001)

Her suggestion of asking students to take notes were also shared by other teachers, like Mr Anderson in School A and Ms Elliott in School D , as a useful strategy for students learning with *BioLogica*.

Since that session, Linda had tried out several versions of online pretest on the genetics reasoning while trying to learn more about *BioLogica*. She also browsed through the information about genetics on the website which the first author created for classroom use in the research. The results of these tests were interpreted to identify Linda's conceptual understanding of genetics, and, in particular, genetics reasoning . Analysis of her online test results indicated she did not have a strongr content knowledge of genetics.

First, she may not have fully understood the process of meiosis and its role in gamete formation, and, in particular, about ploidy and independent assortment of alleles during the process. Second, she also may have problems in using some types of genetics reasoning such as Type IV (effect-to-cause across generations) . Third, like most students in other case studies in this research, her conception about the genes was not sophisticated in that she conceptualised the gene as matter (a thing) more than a process .

Initially, Linda found teaching difficult with her limited content knowledge of genetics. The teaching of genetics is even more difficult for her because she was to start in the middle of the students' learning of that unit "Biological change" . Perhaps, what Linda said in the first interview after she had taught in School B for a few lessons reflected how she had been grappling with her teaching and learning of a conceptually difficult topic. She said:

> "....well. I think it's a difficult subject. It's very hard to explain to the kids just by words and diagrams. So I am hoping when we start using *Biologica* that it's going to sink in easier. I can say at the moment that the kids are finding, especially meiosis, very confusing. They are asking me lots of questions and they are trying to understand it. So...."
>
> (Miss Linda Bell/First Interview/11 June 2001)

Given that she thought genetics is confusing and difficult to explain in words and diagrams, particularly the dynamic process of meiosis, the interactive computer

Paper Presented at the AARE Annual Conference, Brisbane, 2002
Australian Association for Research in Education

program *BioLogica* instantly appealed to her as a visual way of explaining meiosis. She then articulated her thoughts as follows:

> "...Purely I would really like them to get something out of the Meiosis activity. They are struggling to get to grips with this topic. It might just be me because I am an inexperienced teacher; I might not be explaining it well enough. So I am hoping they will get something out of the Meiosis activity.
>
> (Miss Linda Bell/ First Interview/11 June/2001)

In fact Linda had been studying some ICT courses in her university as part of her diploma study and had good computer literacy. Like most other teachers in other case schools, she identified the salient features of an interactive multimedia program. However, her understanding of the functions of multiple representations in interactive multimedia was limited.

Assertion One:

As a preservice teacher, Linda did not have a strong content knowledge for teaching genetics, nor did she have a rich repertoire of instructional strategies; however, she had a good knowledge about ICT upon which she could build her pedagogical knowledge for teaching genetics with BioLogica.

Second Vignette: "I will get more confident with time and practice"

One month on, the first author observed Linda's lesson on 6 June 2001. On that day, the first author did not know that the lesson was the very first one Linda had ever taught in a classroom until she told him later.

When the first author arrived at School B, Linda was still busily preparing for the lesson in the staff room. The first author followed her to her classroom and at the door they were greeted by Mr Nicholson whom the first author met the previous week. Then, the 26 students were entering the classroom; 10 boys and 16 girls were present. The lesson was a successful debut for Linda. She used one workbook activity for students to find out their own genetic traits to illustrate discontinuous variation, one hands-on activity for measuring height and weight to illustrate continuous variation, and finally she summed up the lesson with some notes on the white board for students to copy. According to Lemke's analysis, the classroom talk on that day was a mix of "Teacher Monologues"(p. 49) in which the teacher present material and some "Triadic Dialogues" (p. 8) pattern in which the teacher asks a question, called on students to answer it, and then evaluates their responses. There were very few "Student Questioning Dialogues" (p. 52) in which students ask the teacher questions. Despite few hard questions being asked, as might be expected from a first lesson with this class, Linda was actually under stress and did not have a lot of confidence during those initial lessons. On the following day, the first author could not visit School B as the first author had to interview students at School A at the same time as Linda's lesson. In response to the first author's e-mail message later that day, she wrote:

> "thank you very much for your feedback and reflection on my lessons. I need as much feedback as possible to help me become a better teacher. I am very nervous at the moment, but I will get more confident with time and practice (Miss Linda Bell/e-mail/7 June 2001)

Paper Presented at the AARE Annual Conference, Brisbane, 2002
Australian Association for Research in Education

Then when the first author asked her about her teaching about meiosis on that day in the second e-mail message, she replied to say that said she did not explain the meiosis process well:

> "the lesson today was on meiosis. I'm not sure how well it went. I don't think I explained the process too well. I am hoping that when they use *BioLogica* they will understand it better." (Miss Linda Bell/ e-mail/ 7 June 2001).

Our interpretation of this comment about her teaching was that she did not appeare to have a strong content knowledge upon which she could construct the necessary pedagogical content knowledge in teaching about meiosis. Actually she told the first author later that she did use the overhead projector to show a diagram of the meiosis process but the students did not find that so useful (see Figure 1).

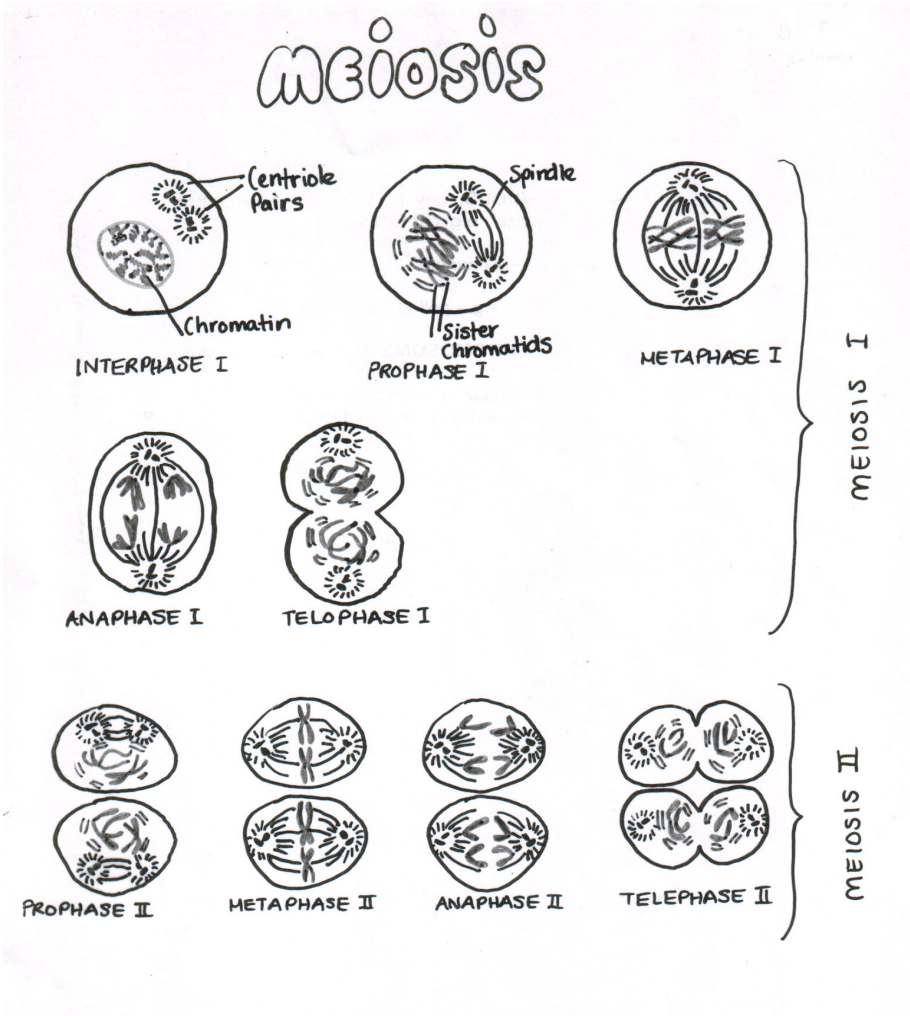

Figure 1. The overhead projection transparency used by Linda in the lesson on meiosis (7 June 2001).

In the overhead projection transparency (OHT) (see Figure 1), she had included too much detail and the esoteric names of the stages of meiosis, which other experienced teachers would not teach in their Year 10 classes. It was likely a copy from a textbook.

Three weeks later, she reflected on this lesson again in the second interview as follows:

Paper Presented at the AARE Annual Conference, Brisbane, 2002
Australian Association for Research in Education

> "I first just went over about gametes and that meiosis only occurs in the male and female gonads. Then I went briefly over the process and then I put on a big overhead of all the different divisions and slowly went through each process. It is quite confusing so I think you need a few lessons to go through it."
>
> (Miss Linda Bell/Second Interview/25 June 2001)

Dissatisfied with her teaching about meiosis, Linda looked forward to using the *BioLogica* activity "Meiosis" in the lesson on the following day. However, as we shall see, she was not able to use the computer program until two weeks later. She ended the second e-mail message of 7 June 2001 by saying "Teaching is very stressful when you are just a prac teacher."

The above vignette portrays how a preservice teacher struggled to teach for the first time and to teach a difficult topic genetics. Linda wished to harness the multiple representations of *BioLogica*, more specifically the computer Dragons ¾ a *constructed entity*, as a *resource for explaining* meiosis. Meiosis, the cell division during the formation of gametes (sperm or eggs in humans), has been well documented to be one of the most difficult parts of genetics to teach and learn in school . What turned out to be a poignant message to preservice teacher educators was the remark in her e-mail about teaching being "stressful". We agree with Roth and Tobin who point out, "prospective teachers continuously experienced the gap between what was required of them in the 'idealistic ways' of their university courses versus teaching in the classroom."(p. 745).

Third Vignette: "Bright kids asking hard questions"

On 12 June 2001, Linda had struggled through another week of teaching in School B. It was a Tuesday. She taught a very interesting but challenging lesson on the inheritance of human eye colours. Linda's Year 10 science lesson started at 8:40 am. As usual, the first author followed Linda to the science classroom. Girls and boys were still waiting outside the classroom chattering rather noisily. When they were seated, the first author noticed there were 17 girls and 10 boys. Mr Nicholson was in the classroom most of the time while Linda was teaching.

Soon Linda started to teach. First, she tried to link students' thinking to what she had taught about variation on 6 June by asking them to suggest some examples. The interactions were typically of a "Triadic Dialogue" pattern . Then, she moved to the next part of the lesson by showing two OHTs (see Figure 2 and Figure 3) about the inheritance of eye colours. Linda's "Teacher Monologue" with the two OHTs being projected in sequence caused some agitation in the class. Students tried to look at each other's eyes. A boy, who always asked questions, started a "Student Questioning Dialogue" as follows:

> Student: Do my parents need to have brown eyes if I have dark brown ?
>
> Miss Bell: Yes, they will most likely have brown eyes.
>
> (Miss Linda Bell's journal/ 12 June 2001)

Then, the class became rather noisy as they had to work in groups of two to find out their offspring's eye colours imagining they were parents.

Paper Presented at the AARE Annual Conference, Brisbane, 2002
Australian Association for Research in Education

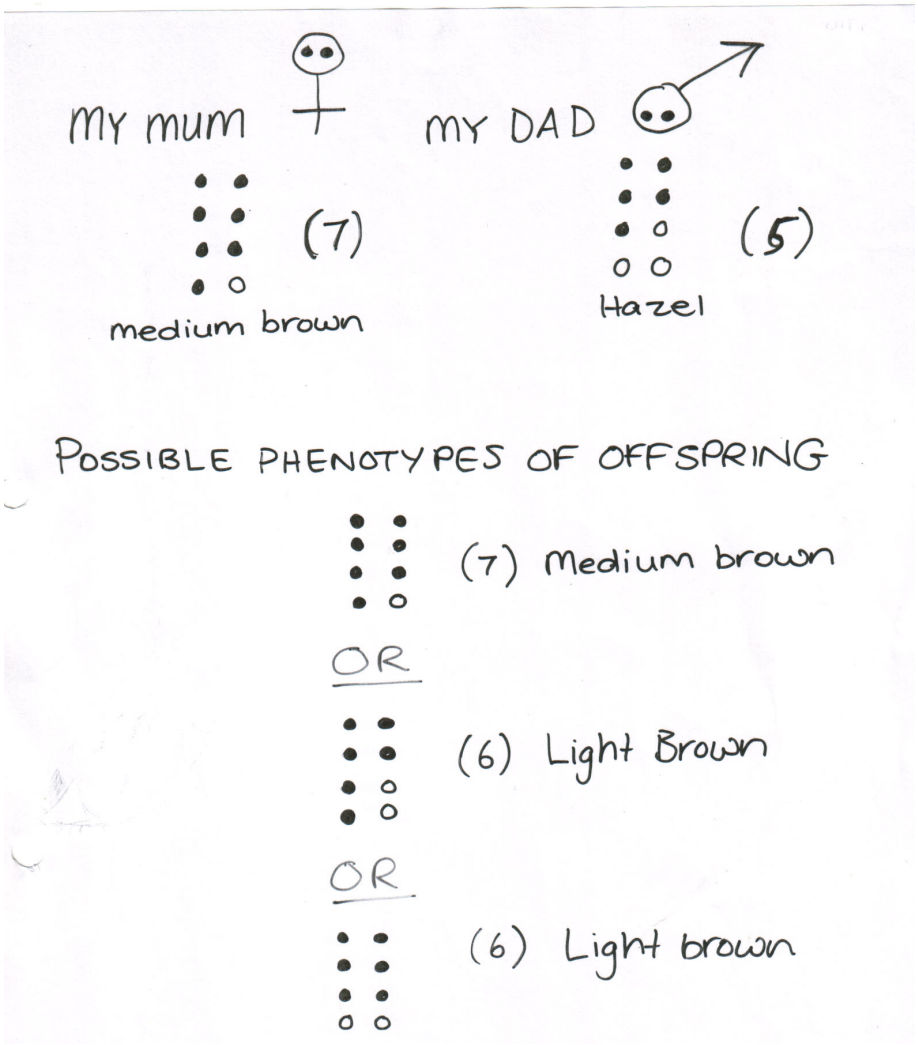

Figure 2. The first overhead projection transparency used by Linda in the lesson on inheritance of eye colour (12 June 2001).

NUMBER OF CONTRIBUTING EYE COLOUR ALLELES	PHENOTYPE
8	Dark Brown
7	Medium Brown
6	Light Brown
5	Hazel
4	Green
3	Grey
2	Dark Blue
1	Medium Blue
0	Light Blue

Figure 3. The second overhead projection transparency used by Linda in the lesson on inheritance of eye colour (12 June 2001).

Paper Presented at the AARE Annual Conference, Brisbane, 2002
Australian Association for Research in Education

Next, three groups volunteered to present on the white board their results which were similar to Figure 2. Their "offspring" were predicted to have eye colours along a continuum from light blue to dark brown. Linda commented briefly on their results. Then the same boy started another "Student Questioning Dialogue" as follows:

> Student: You say there is only eight different colours. How can you call it continuous variation?
>
> Miss Bell: I was only giving an example. There are really many other shades of eye colours. I was categorising the major colours. (Miss Linda Bell's journal/12 June 2001)

The boy appeared to be dissatisfied with the answer but Linda had no time to continue with this conversation. She turned to the white board to summarise what she though students needed to know by writing: "Variation is due to the type of inheritance controlled by multiple genes or multiple alleles" (The first author's field notes/12 June 2001). Students were invited to suggest some ideas and come to the front to write them on the white board. Students, especially the girls, were very enthusiastic in suggesting and writing their ideas on the board.

It was about 9:40am, less than 10 minutes before the end of the lesson. Linda was about to end the lesson by saying " Any questions? Please. No questions?" Then the hard question came. One boy had just asked a question and the teacher was talking to him when two boys raised their hands. Linda came over to them. One boy asked a question that made the whole class laugh. Then, the class became rather noisy and Linda said "Last five minutes please listen". The lesson soon ended and the boys and girls began to leave the classroom. Linda told the first author that the boy asked her to explain why a man can have one brown eye and one blue eye, and that he said that he read about it somewhere.

On the next day, Linda gave the class an Internet URL address and explained to the class that the man with one blue eye and one brown suffered from *Waardenburg Syndrome* (named after a Dutch doctor who discovered it), which is an inherited disorder often characterized by varying degrees of hearing loss and changes in skin and hair pigmentation. The students were happy to know the answer. Linda probably thought that the boy's hard question was not meant to be a trick for her.

In the second interview after her field experience, when asked if she had any difficulties in her very first teaching experience, Linda said:

> I didn't find any real difficulties except that the kids were so bright and were asking some very hard questions that I did not know and I had to go home and research myself about the question. I sometimes would spend hours on the Internet especially about the one blue eye and one brown eye. So was probably the hardest part and it was quite embarrassing not being able to answer some of their questions.
>
> (Miss Linda Bell/Second Interview/25 June 2001)

In the above vignette it can be seen that the last question asked by the student is about one uncommon genetic disorder which other experienced teachers may not have the knowledge about it. It may not be fair to judge a new teacher's content knowledge with this example. However, the Waardenburg syndrome asked by the student did bring to the fore how Linda used her PCK in teaching genetics. Linda was able to expand her knowledge in response to students' learning demands and she did use ICT as strategies in improving her teaching.

Assertion Two:

Paper Presented at the AARE Annual Conference, Brisbane, 2002
Australian Association for Research in Education

As Linda was dissatisfied about her teaching in the first few lessons, she endeavoured to harness technology for better representation of genetics and to expand her content knowledge of genetics.

Fourth Vignette: "they need to be guided through"

It was a Thursday 14 June 2001, the end of Linda's second week of practice teaching. Today, the students will do their online test and start to use *BioLogica* activity "Meiosis".

One week earlier, she taught about meiosis but was dissatisfied about her explanation. She had actually wished to let the students engage in the *BioLogica* activity "Meiosis" the next day but was unable to use the computer room until the following Thursday. Linda e-mailed the first author on the previous day that it would be useful if the first author was in the school earlier. Because of the technical issues in School A, the first author went to see Mr Smith, the IT person, two weeks earlier to discuss with him about the installation of *BioLogica* and handed him a CD-ROM with the software. However, the first author was unable to see him again on the previous day to ensure that students could use the program when Linda had the lesson in the computer room. Nor could Linda and the first author have access to the computer room to try out the program and the online material on our request. Teachers were too busy but Linda told the first author that the Mr Smith had promised to install *BioLogica* in all machines on that day.

The lesson soon started in the computer room. All students could successfully log on to access their virtual classroom which the first author had created in collaboration with Linda on the website at Curtin University. They could read all the pages but somehow they were unable to use the online pretest. Linda talked to Mr Nicholson but could not find Mr Smith. Then, next, students could not run the *BioLogica* program either. They discovered that the program had not been installed. Linda discussed with the first author and decided that students could use the discussion forum and use other web-based material about genetics. The students were already exploring the different functions in the virtual classroom. For the next half a hour, the students were totally absorbed in the discussion forum, enjoyed the activity, and posted more than 150 articles but very few of such writings were about genetics. Some postings were jokes or threats to other students. Linda tried to post a few questions to guide their discussion but was unable to lead the discussion. Mr Nicholson appeared to be unhappy about what had happened.

In one of Linda e-mails on that day, she reflected that day's experience as follows:

> I think now that the students have had their fun they should be more responsible. We will soon see... I get very frustrated and stressed out. I think it would be much easier if I was a qualified teacher as I could control the students more, and I would have more authority over them. As I am a guest at School B too, I must do what I am told. I will email you tomorrow to tell you how we will use *BioLogica* after talking to Mr Smith.

She again revealed her stressful feeling and became frustrated when the teachers in School B were too busy to help but she understood she was just a guest.

The above vignette shows that Linda's teacher supervisor and Mr Smith were too busy to arrange for Linda to use the interactive multimedia program as often as she had wished to. Eventually, Linda was only able to use computers in two lessons including one with *BioLogica* activities.

Paper Presented at the AARE Annual Conference, Brisbane, 2002
Australian Association for Research in Education

Finally, on 21 June 2001, a Thursday in the third or the last week of Linda's practice teaching, she had a very rewarding lesson having the students engaged in two*BioLogica* activities "Introduction" and "Meiosis" (see Figure 4 for a snapshot of "Meiosis"). Linda was glad that the program worked perfectly with no glitches. Mr Nicholson, who had never used the computer in teaching science, walked around the computer room looking at what the students were doing and talked to some of them.

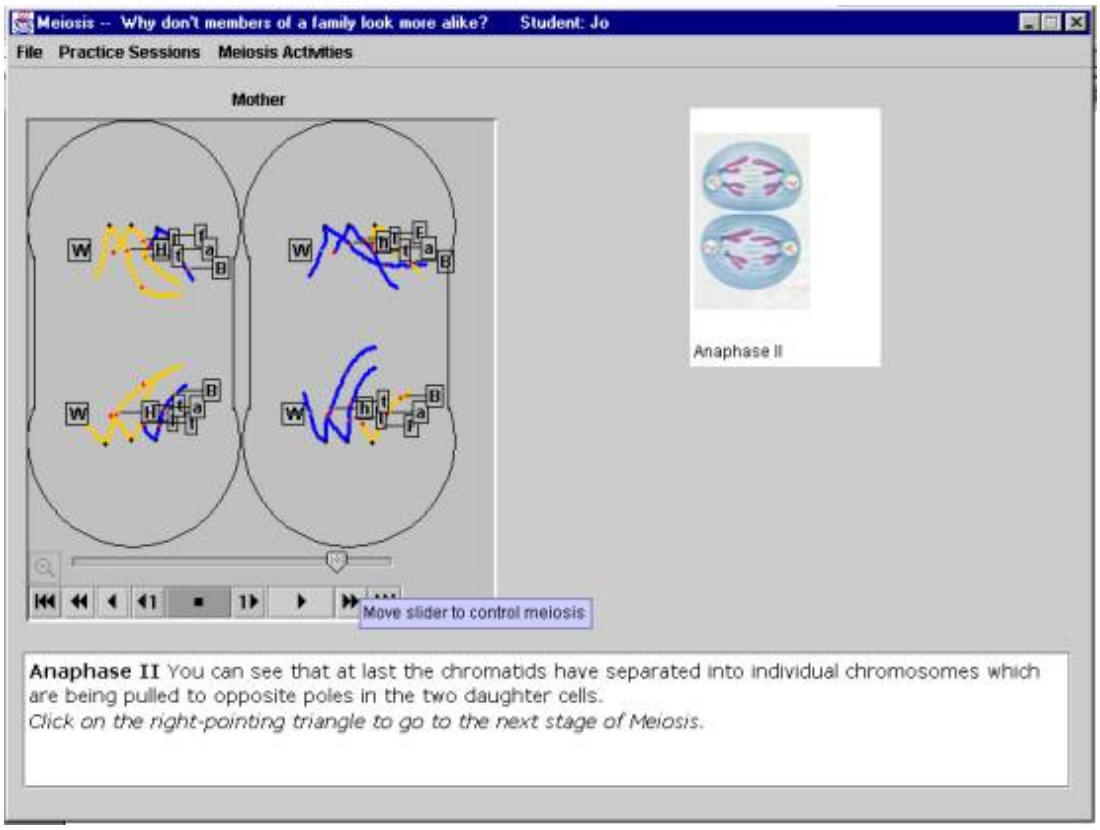

Figure 4. A snapshot of the BioLogica activity "Meiosis" showing animation of the meiosis process with complementary information in the text window to explain the visual-graphical representations.

At the start of the lesson, Linda first briefed the class on how to run the program. She then moved around to answer the students' questions and discussed with some group of students. The following is a dialogue captured by the videotape at 12:21 am when two boys tried to get their teacher's attention:

> Student: I killed one of the Dragons.
>
> Miss Bell: That's fine. Work out what the lethal genes are.
>
> Student: How do I do it?
>
> Miss Bell: Go back [to the previous screen] to remember what the genes were. Take some notes about each Dragon.

At 11.28am, the teacher reminded some girls that they could talk to each other and help each other through the activities. Video-recording that started at 11.29 am showed that one girl interacted with *BioLogica* in following dialogues in the text boxes:

Paper Presented at the AARE Annual Conference, Brisbane, 2002
Australian Association for Research in Education

> *BioLogica* Question: What did you notice as you examined the chromosomes?
>
> Student's answer: The male had an X and Y chromosome, and the female has two X chromosomes.
>
> *BioLogica* Question: In particular, how do the chromosomes of the male and female Dragons differ?
>
> Student answer: The male Y chromosome had less genetic information than the females X chromosomes. (Video Images / 21 June 2001)

At 11.30am, two girls asked the teacher about dominant and recessive genes. She reminded them that if they could not remember they could go back to previous screens to refresh their memory.

Our interpretation is that Linda could have provided better scaffolding to the students while they were engaged in the *BioLogica* activities in the computer room if she had conceptually linked the computer representations (Dragon genetics) to classroom teaching (human genetics) as did experiences teachers in other case studies .

Assertion Three:

Linda's implementation of BioLogica activities to teach genetics for understanding was impeded by two kinds of factors: (1) institutional factors such as teacher being too busy to support her use of technology and (2) epistemological factors associated with her teacher knowledge.

Overall, the computer session on 21 June 2001 was a success at least in motivating students to learn about the dynamic process of meiosis. Probably, the students were able to relate genetics reasoning to meiosis in solving problems but little data about student learning outcomes were collected. As observation of the lesson on 21 June indicated, Linda implicitly used the metaphor of the teacher as a guide in the computer learning environment. In the second interview, when asked what role she thought a teacher should play in the computer room where students were using *BioLogica* activities, Linda said the following:

> From my own experience in observing some computer classes the teachers sort of just say log on to your computers and they let the kids do their own work without any guidance. The students need some timing and restrictions and they need to be guided through. Otherwise they will just have fun and not learn anything. So the teacher does play an important role. You can't just think the computers are going to look after the kids and be their teacher. You have to be a teacher as well.

On reflection she found using the *BioLogica* activity "Meiosis" plausible for teaching meiosis. When teaching of meiosis in the classroom she had once tried to use visual aids (see her OHT in Figure 1) to help understanding but did not find it so useful (see First Vignette). Linda wished to use the program the next day after she had taught meiosis in the classroom as she said the second interview. "[I] think it would have been good to use *BioLogica* the very next day." The reality was that she needed to wait for two weeks before she could use the program and this created problems for her and the students in that their classroom learning was not so closely aligned to the computer activities.

After the field experience in School B, she described and reflected upon her teaching in terms of helping student to understand the meiosis process through visualising what is going on:

Paper Presented at the AARE Annual Conference, Brisbane, 2002
Australian Association for Research in Education

> Yes, especially the Meiosis activity. I found the kids really beginning to understand the whole process when doing the activity with *BioLogica* ¾ they could really see what was going on. It was all falling into place when they were using *BioLogica*.
>
> (Miss Linda Bell/Second Interview/25 June 2001)

Linda e-mailed the first author on 23 June that she had spoken to two girls after the lesson. They told their teacher that they enjoyed using *BioLogica* and it was very helpful in their understanding of meiosis. These two students did the online test (a version similar to the posttest) with good results. A few comments from other students was similar in that the visual process of the dividing cells was very useful. Linda also highlighted the social and affective dimension of learning. She commented about the lesson on 21 June 2001 when students used *BioLogica* activities for the first and the only time as follows:

> I think it [Meiosis activity] worked very well. It was good in the fact that there was a few students moving through the activities very quickly and it was good that they could move on at their own pace. They were asking lots of questions, so it was provoking, a lot of questions. The were interacting well together. So I think it worked out very well.
>
> (Miss Linda Bell/Second Interview/25 June 2001)

When the first author asked her what the students were discussing while using the program she said:

> Most were commenting on meiosis and the visual representation of meiosis. They were really playing around with that. They liked how they could make their own babies [*BioLogica*Dragons].
>
> (Miss Linda Bell/Second Interview/25 June 2001)

As for student learning, she believed they did learn from the *BioLogica* activities "Introduction" and "Meiosis" as she said:

> In general I think they learnt something from me. By using *BioLogica* it gave good revision to the students as it went over previous classes. I think by using *BioLogica* it would have been good revision as they have a test next week (Miss Linda Bell/Second Interview/25 June 2001).

Despite some initial frustrations, Linda enjoyed her experience in using *BioLogica* and the online classroom virtual classroom in her teaching and thought that both she and her students really learnt about genetics in a different way.

Assertion Four:

Linda's decision about instructional strategies was underpinned by a learning perspective commensurate with social constructivist ideas as indicated by the metaphor of the teacher as a guide in the computer classroom.

Paper Presented at the AARE Annual Conference, Brisbane, 2002
Australian Association for Research in Education

Linda's Pedagogical Content Knowledge

Despite not having strong content knowledge about genetics, as the above four vignettes show, Linda struggled to learn together with her students in making a small attempt to teach genetics in an innovative way that was unprecedented in School B.

We argue that PCK here pertains to an amalgam of two types of content knowledge (genetics and learning technologies) and a special kind of pedagogical knowledge (how to teach genetics with learning technologies in general and *BioLogica* in particular). As the above four vignettes show, Linda had improved her PCK through the three weeks of field experience in which she talked and thought about using *BioLogica* and then actually used it to teach genetics, particularly in explaining the meiosis process. Linda improved her PCK in two ways.

First, as she was responsive to students' questions and learning for understanding, she was able to expand her content knowledge of genetics and thus the conception teaching that content knowledge. Not only did she work very hard to read more, she also used the ICT to search for new information and communicate with the researcher (the first author) for feedback. After the field experience she was also able to reconceptualise genetics knowledge. Genetics is difficult to teach not just for her but also because "it is still very new and there... new advances and ideas arising" and " continually changing and advancing" (Miss Linda Bell/Second Interview/25 June 2001).

Second, Linda's habitual reflection upon her practice was likely to contribute to her learning as a preservice teacher. Reflection promotes an interplay between a teacher's own personal pedagogical knowledge to general pedagogical knowledge . Accordingly, reflection allows the personal pedagogical knowledge to be broadened and made more objective while pedagogical conceptions are contextualised. Reflection thus brings to fruition a new type of knowledge ¾ context-specific pedagogical knowledge useful for guiding teachers' actions and decisions. Drawing on the model of Gess-Newsome and that of Morine-Dershimer and Kent , we attempt here to portray a possible pathway of Linda's development of her PCK during her field experience (See Figure 5).

Figure 5. A flow chart tracing a possible chain of changes in Linda's PCK; based on the models of Gess-Newsome and Morine-Dershimer .

Figure 5 illustrates a possible flow chart showing how Linda might have developed her PCK. Her "Content Knowledge" (about teaching genetics with technology) was constructed upon her studies about genetics in schools and universities, her reading and learning from different materials including online resources and the researcher's online tests and feedback; and also upon her course work on ICT, her experiences trying out *BioLogica*, and other web-based materials. Her "General Pedagogical Knowledge" was likely built on her course work and the previous field experience of observing lessons. Of particular importance in the flow chart is the juncture "Reflection" that bridged her "General Pedagogical Knowledge" and her "Personal Pedagogical Knowledge", which she had developed during the practice teaching, and transformed these to "Context-specific Pedagogical Knowledge".

Paper Presented at the AARE Annual Conference, Brisbane, 2002
Australian Association for Research in Education

Reflection thus contributed to the construction of a contextualised pedagogy in the development of her PCK. As Wallace and Louden argue, since Dewey's time, it has been a centre of criticism of teachers lacking in a disposition towards a reflective practice and it is still the case today. We believe that Linda is a fledgling reflective practitioner.

Discussion and Conclusions

On the basis of the above data analysis, interpretations and assertions, we have summarised the findings as follows:

1.As a preservice teacher, Linda did not have a strong content knowledge, nor a rich repertoire for teaching genetics; however she had a good knowledge about ICT.

2.Dissatisfied about her first experience teaching genetics, Linda expanded her content knowledge and attempted to harness the multiple representations of *BioLogica* as strategies to improve her teaching; therefore she was able to develop her pedagogical content knowledge (PCK) for teaching genetics with *BioLogica*.

3.Linda's implementation of *BioLogica* activities to teach genetics for understanding was impeded by (a) institutional factors such as the support from the school for using technology in teaching, and (b) epistemological factors associated with her own PCK.

4.Linda's decision about using technology as instructional strategies was underpinned by a social constructivist perspective through the metaphor of the teacher as a guide in the computer classroom.

5.Reflection appeared to provide opportunities for Linda to learn from the interplay between teaching theory and teaching practice in developing a pedagogical knowledge specific to the classroom context, an important component in her PCK.

We have attempted to analyse, interpret and trace Linda's development of a special kind of PCK while teaching genetics with *BioLogica* and how reflection contributed to such development. In interpreting narrative stories of teachers, there are inevitably sources of instability that would make the findings contestable. As for "the problem of authenticity" (p. 6), we have tried carefully while writing this paper to respect Linda's voice and her students' voices by using numerous direct quotes from multiple sources. We believe, as Guba and Lincoln suggest, that the first author's "persistent observation" (p. 237) of Linda's lessons, the second author acting as the "debriefer" (p. 238) in regular discussions of the data analysis and interpretation, and Linda's "member checks" (pp. 238-239) of interview and lesson transcripts, have increased the "credibility" (p. 236) of this case study. However, the findings of this case study have limitations in that almost no data about student learning outcomes were collected.

The story of Linda in this paper, illustrated by the four vignettes, highlights how she developed her pedagogical content knowledge (PCK) while teaching genetics with technology. Linda's story points to a longstanding issue that university programmes do not adequately prepare preservice teachers to meet the diverse demands and challenges of teaching in today's classrooms . It appears to be an important agenda in preservice teacher education for filling the gap between theory and praxis .

The findings of this case study have some implications for science teacher education and research. First, to help preservice teachers to use ICT in teaching for understanding, teacher

Paper Presented at the AARE Annual Conference, Brisbane, 2002
Australian Association for Research in Education

education courses should be geared towards a more domain-specific approach to classroom use of ICT. Second, as computer-based multiple representations have provided new opportunities for learning but also new challenges for teaching, teachers' PCK for using ICT in subject areas has become a gap in teacher education and research. Both teacher education and research agendas should put more emphasis on this special type of PCK. Third, it has been a persistent criticism that despite the huge expenses on computing facilities in schools, the impact of computers on school learning is still not obvious . We believe that teachers may not understand how to improve student learning with interactive multimedia, particularly in domain-specific areas. With multiple representations becoming ubiquitous in today's computer-based learning environments, it may be useful for preservice teacher education to include an introduction to the pedagogical functions of multiple representations or multiple external representations (MERs), that are "to complement" information and processes, to "constrain" interpretation, and to "construct" understanding .

Acknowledgements

We wish to thank the preservice teacher and the Year 10 students for their participation, and the School B staff for their support and help in this study. We are grateful to Dr Paul Horwitz of the Concord Consortium of the USA for permission to use *BioLogica* for research in Australian schools. We dedicate this paper to the late Professor David Squires (King's College, the University of London) whose lectures during an Institute held in our education centre in 2000 inspired the first author to work on his doctoral research project about learning with multiple representations.

References

Ainsworth, S. E. (1999). The functions of multiple representations. *Computers & Education, 33*(2/3), 131-152.

Ainsworth, S. E., Bibby, P. A., & Wood, D. J. (1997). Information technology and multiple representations: New opportunities - new problems. *Journal of Information Technology for Teacher Education, 6*(1), 93-104.

Bahar, M., Johnstone, A. H., & Hansell, M. H. (1999). Revisiting learning difficulties in biology. *Journal of Biological Education, 33*(2), 84-86.

Beyerbach, B., Christie, W., & Vannatta, R. (2001). From teaching technology to using technology to enhance student learning: Preservice teachers' changing perception of technology infusion. *Journal of Technology and Teacher Education, 9*(1), 105.

Concord Consortium. (2001). *BioLogica*. Concord Consortium. Retrieved 8 October, 2001, from the World Wide Web: http://biologica.concord.org

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher, 23*(7), 5-12.

Paper Presented at the AARE Annual Conference, Brisbane, 2002
Australian Association for Research in Education

Education Department of Western Australia. (1987). *The unit curriculum: Science (science and technology)*. Perth: Education Department of Western Australia.

Erickson, F. (1986). Qualitative methods in research on teaching. In M. Wittrock (Ed.), *Handbook of research on teaching* (pp. 119-161). New York: Macmillan.

Gallagher, J. J. (Ed.). (1991). *Interpretive research in science education* (Vol. 4). Manhattan, KS: National Association for Research in Science Teaching (NARST), Kansas State University.

Gess-Newsome, J. (1999). Pedagogical content knowledge: An introduction and orientation. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical content knowledge* (pp. 3-17). Dordrecht: Kluwer Academic Publishers.

Grossman, P. (1990). *The making of a teacher: Teacher knowledge and teacher education*. New York: Teachers College Press.

Guba, Y., & Lincoln, Y. S. (1989). *Fourth generation evaluation*. Newbury Park, CA: Sage Publications.

Hackling, M. W., & Treagust, D. F. (1984). Research data necessary for meaningful review of grade ten high school genetics curricula. *Journal of Research in Science Teaching, 21*(1), 197-209.

Hickey, D. T., & Kindfield, A., C. H. (1999, April). *Assessment-oriented scaffolding of student and teacher performance in a technology-supported genetics environment.* Paper presented at the annual meeting of the American Educational Research Association, Montreal, Canada.

Kindfield, A. C. H. (1994). Assessing understanding of biological process: Elucidating students' models of meiosis. *The American Biology Teacher, 56*(6), 367-371.

Lawless, K. A., Smith, E. V., Kulikowich, J. M., & Owen, S. V. (2001). Preservice teachers' beliefs about the relationships between domain knowledge and instructional media. *Interanational Journal of Instructional Media, 28*(3), 261-270.

Lemke, J. L. (1990). *Talking science:Language, learning, and values*. Norwood, NJ: Ablex Publishing Corporation.

Lemke, J. L. (1998). Analysing verbal data: Principles, methods and problems. In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 1175-1189). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Lewis, J., Leach, J., & Wood-Robinson, C. (2000). Chromosomes: The missing link--young people's understanding of mitosis, meiosis, and fertilisation.*Journal of Biological Education, 34*(4), 189-199.

Paper Presented at the AARE Annual Conference, Brisbane, 2002
Australian Association for Research in Education

Loughran, J., Milroy, P., Berry, A., Gunstone, R., & Mulhall, P. (2001). Documenting science teachers' pedagogical content knowledge through PaP-eRs.*Research in Science Education, 31*, 289-307.

Loughran, J., Mitchell, I., Neale, R., & Toussant, D. (2001). PEEL and the beginning teacher. *Australian Educational Researcher, 28*(2), 29-52.

Merriam, S. B. (1998). *Qualitative research and case study applications in education*. San Francisco, CA: Jossey-Bass Publishers.

Morine-Dershimer, G., & Kent, T. (1999). The complex nature and sources of teachers'pedagogical knowledge. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical content knowledge* (pp. 21-50). Dordrecht: Kluwer Academic Publishers.

Ogborn, J., Kress, G., Martin, I., & McGillicuddy, K. (1996). *Explaining science in the classroom*. Buckingham: Open University Press.

Pearson, J. T., & Hughes, W. J. (1988). Problems with the use of terminology in genetics education: 1, A literature review and classification scheme.*Journal of Biological Education, 22*(3), 178-182.

Poole, P. (2000). Information and communications technology in science education: A long gestation. In J. Sears & A. Smith & P. Sorensen (Eds.), *Issues in science teaching* (pp. 209-218). London and New York: RoutledgeFalmer.

Putnam, R. T., & Borko, H. (1997). Teacher learning: Implications of new views of cognition. In B. J. Biddle & T. L. Good & I. F. Goodson (Eds.),*International handbook of teachers and teaching* (pp. 1223-1296). Dordrecht: Kluwer Academic Publishers.

Roth, W.-M., & Tobin, K. (2001). Learning to teach science as practice. *Teaching & Teacher Education, 17*, 741-762.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Shulman, L. S. (1987). Knowledge and teaching: Foundation of the new reform. *Harvard Educational Review, 57*(1), 1-22.

Stake, R. E. (1995). *The art of case study research*. Thousand Oaks, CA: Sage Publications Inc.

Stewart, J. H. (1982). Difficulties experienced by high school students when learning basic Mendelian genetics. *The American Biology Teacher, 44*(2), 80-84, 89.

Stewart, J. H., Hafner, R., & Dale, M. (1990). Students' alternate views of meiosis. *The American Biology Teacher, 52*, 228-232.

Paper Presented at the AARE Annual Conference, Brisbane, 2002
Australian Association for Research in Education

Stuart, C., & Thurlow, D. (2000). Making it their own: Presevice teachers' experiences, beliefs, and classroom practice. *Journal of Teacher Education, 51*(2), 113-121.

Tsui, C.-Y. (2002, November). *Learning with multiple representations in a technology-rich school: A case study in a Year 12 TEE class.* Paper presented at the the 25th annual conference of the Western Australian Science Education Association (WASEA), Canning College, Perth, Western Australia.

Tsui, C.-Y., & Treagust, D. F. (2002, August). *Learning genetics with multiple representations: Preliminary findings in a laptop school.* Paper presented at the 17th Annual Research Forum of the Western Australian Institute for Educational Research (WAIER), Edith Cowan University, Perth, Western Australia.

Tsui, C.-Y., & Treagust, D. F. (in press-a). Genetics reasoning with multiple external representations. *Research in Science Education*.

Tsui, C.-Y., & Treagust, D. F. (in press-b). Motivational aspects of learning genetics with interactive multimedia. *The American Biology Teacher*.

Tyson, L. M., Venville, G. J., Harrsion, A. L., & Treagust, D. F. (1997). A multidimensional framework for interpreting conceptual change events in the classroom. *Science Education, 81*, 387-404.

Venville, G. J., & Treagust, D. F. (1998). Exploring conceptual change in genetics using a multidimensional interpretive framework. *Journal of Research in Science Teaching, 35*, 1031-1055.

Wallace, J., & Louden, W. (2000). *Teachers' learning: Stories of science education*. Dortrecht, The Netherlands: Kluwer.

Wood, R. (1993). Taking the plunge into the gene pool: teaching and learning in genetics. *Research in Science Education, 23*, 337-344.

Wood, R. (1996). *From my DNA to Darwin: Learning and teaching in genetics.* Unpublished D.Phil Thesis, University of Waikato, Hamilton.