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ABSTRACT

Explores the conceptual change of two classes of grade 10 students (n=48) in their genetics learning in an Australian girls' school that uses laptop computers. The study used an interpretive, case-based design with multiple data collection methods and a multidimensional conceptual change framework. Over seven weeks, the students learned genetics that included work on their laptop computers with BioLogica, a multimedia program, and online multimedia about human and molecular genetics. Multiple external representations (MERs) in multimedia, as researchers claimed, support cognitive processes and problem solving. Given that representability is essential for making difficult concepts intelligible, MERs provide new opportunities for learning genetics. Findings indicated that most students were highly motivated in their learning and that over half of them enjoyed learning with multimedia on human and molecular genetics more than with BioLogica. Most students improved their genetics reasoning after instruction but only in easier reasoning types. Some students, however, had developed sophisticated conceptions and the status of their conceptions was intelligible, plausible, and fruitful. The findings have implications for making better pedagogical use of multiple representations in teaching for conceptual change. (Author)

Learning Genetics with Multiple Representations:

A Three Dimensional Analysis of Conceptual Change

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Abstract

This paper explores the conceptual change of two classes of Grade 10 students (n = 48) in their genetics learning in an Australian girls' school that uses laptop computers. The study used an interpretive, case-based design with multiple data collection methods and a multidimensional conceptual change framework. Over seven weeks, the students learned genetics that included work on their laptop computers with *BioLogica*, a multimedia program, and online multimedia about human and molecular genetics. Multiple external representations (MERs) in multimedia, as researchers claimed, support cognitive processes and problem solving. Given that representability is essential for making difficult concepts intelligible, MERs provide new opportunities for learning genetics. Findings indicated that most students were highly motivated in their learning and that over half of them enjoyed learning with multimedia on human and molecular genetics more than with *BioLogica.* Most students improved their genetics reasoning after instruction but only in easier reasoning types. Some students, however, had developed sophisticated conceptions and the status of their conceptions was intelligible, plausible, and fruitful. The findings have implications for making better pedagogical use of multiple representations in teaching for conceptual change.

Objective

This paper reports a case study of two Grade 10 classrooms in a girls' school with laptops when the students (n = 48) learned genetics over seven weeks with computer multimedia that feature linked multiple external representations (MERs) (Ainsworth, 1999).

The original focus on the use of *BioLogica* (Concord Consortium, 2001) was extended to some online multimedia on human and molecular genetics (Cold Spring Harbour Laboratory, 2002) which the teachers also used in their teaching. The major objective of the study reported here is about the extent to which computer multimedia brought about students' conceptual change along the social/affective, epistemological, and ontological dimensions (Tyson, Venville, Harrison, & Treagust, 1997). Within these dimensions we attempted to determine the status (Thorley, 1990) of student interviewees' conceptions of genetics after instruction.

Introduction

This study is significant because few studies on learning with multimedia used a multidimensional conceptual change framework.

Genetics has now become privotal in the biological sciences and increasingly related to human affairs and is central to controversial debates such as genetically modified foods and cloning. While international researchers over the past two decades have reiterated that genetics remains conceptually and linguistically difficult to teach and learn in schools (e.g., Bahar, Johnstone, & Hansell, 1999; Johnstone & Mahmoud, 1980; Stewart, 1982; Wood, 1996), the Australian counterparts have had similar findings (Hackling & Treagust, 1984; Venville & Treagust, 1998). Using Tyson et al.'s (1997) framework, we report in this paper a three-dimensional analysis of students learning genetics in a laptop school for girls. We also examine the status of one student's conception using Thorley's (1990) *status analysis categories*, which few conceptual change researchers have so far adopted in analysing the status of students' conceptions.

Theoretical Underpinnings

Learning for Conceptual Change

The conceptual learning perspective is now generally used for understanding and improving science education. Since Posner, Strike, Hewson, and Gertzog (1982) proposed the conceptual change model, researchers have endeavoured to advance the model beyond the original epistemological perspective.

The theoretical frameworks of three groups of researchers are relevant to this study. First, Pintrich, Marx, and Boyle (1993) suggested applying research on student motivation to the process of conceptual change because of "the theoretical difficulties of a cold, or overly rational, model of conceptual change" (p. 167). They discussed four motivational constructs—goals, values, self-efficacy, and control beliefs—as potential mediators of conceptual change. Second, Chi, Slotta and de Leeuw (1994) suggested an ontological perspective for interpreting conceptual change. They proposed three basic ontologically distinct categories to which physical entities of the world can belong: *matter*, *processes* and *mental states* and two kinds of conceptual change: a change within an ontological category or a change across ontological categories. Third, Tyson, Harrison, Venville, and Treagust's (1997) proposed a multidimensional model—that incorporate the epistemological, social/affective and ontological perspectives—for interpreting classroom conceptual learning of science. The model has proved to be a robust framework in a number of recent case studies (e.g., Harrison & Treagust, 2001; Venville & Treagust, 1998).

In this paper, the focus is on genetics reasoning used in problem solving which has to be built upon an understanding of biological subcellular processes underlying the concepts and their relations (Kindfield, 1992). Hickey and Kindfield's (1999) six types of genetics reasoning used in assessing the GenScope[1] learning environment were adopted in this study for interpreting the student reasoning and problem solving. These six genetics reasoning types are shown in Table 1.

[1] *GenScope* was a predecessor computer program based on which *BioLogica* (Concord Consortium, 2002) was developed by the same research group headed by Dr Paul Horwitz of the Concord Consortium of the USA.

Table 1

The Six Types of Reasoning in Genetics Problem Solving along Two Dimensions adapted from Hickey and Kindfield (1999).

		Domain-General Dimension of Reasoning (Novice ◄——► Expert)		
		Cause-to-effect	Effect-to-cause	Process Reasoning
Domain-Specific Dimension of Reasoning (simple ▲	Between-generations	Monohybrid Inheritance: Mapping Genotype to Phenotype (Type II)	Monohybrid Inheritance: Mapping Phenotype to Genotype (Type IV)	Punnett Squares (input/output reasoning): Meiosis process (event reasoning. Mitosis process [a] (Type VI)
▼ complex)	Within-generations	Mapping Genotype to Phenotype (Type I)	Mapping Phenotype to Genotype (Type III)	Mapping information in DNA base sequence (genotype) to amino acid sequence in protein synthesis (phenotype)[b] (Type V)

[a] not included in Hickey and Kindfield's (1999) original types

[b] not included in Hickey and Kindfield's (1999) original types but adapted from Venville and Treagust's (1998) sophisticated conception of gene as being a "productive sequence of instructions".

Multidimensional Conceptual Change Model and Status Analysis

In this study, student learning in terms of genetics reasoning was interpreted using Tyson et al.'s (1997) multidimensional conceptual change framework and Thorley's (1990) status analysis categories.

First, Tyson, Venville, Harrison, and Treagust's (1997) multidimensional conceptual change model brings together the epistemological, social/affective and ontological perspectives and to encourages researchers and teachers to view conceptual change from these three dimensions. For instance, Venville and Treagust (1998) used this framework for determining the status of students' gene conceptions. Second, the *status* of a person's idea indicates how much the person knows it (find it *intelligible*), accepts it (finds it *plausible*) and finds it useful (or *fruitful*) (Hewson, 1981). The construct status—central to Posner et al.'s (1982) conceptual change model—is not easy to determine. As such, we find Thorley's (1990) status analysis categories useful for determining status. Accordingly, the status of a conception is determined by a set of status elements for intelligibility, plausibility and fruitfulness (see Table 2).

Table 2

A simplified version of Thorley's (1990) status analysis categories for determining conceptual status

Status of Conceptions	Status Elements (in upper case)
INTELLIGIBILITY	*Representational modes* : INTELLIGIBILITY ANALOGY, IMAGE, EXEMPLAR and LANGUAGE
PLAUSIBILITY	*Consistency factors* : OTHER KNOWLEDGE, LAB EXPERIENCE, PAST EXPERIENCE, EPISTEMOLOGY, METAPHYSICS, PLAUSIBILITY ANALOGY; *other factors*: REAL MECHANISM
FRUITFULNESS	POWER, PROMISE, COMPETE and ENTRINSIC

Two status elements for fruitfulness are particularly useful in this study in determining status of students' gene conceptions. POWER means that the conception has wide applicability, whereas PROMISE means that the student looks forward to what the new conception might do. As Hewson and Lemberger (2000) argued, "status—a construct originating in conceptual change theory—is the hallmark of all forms of conceptual learning" (p. 123).

New Computational Perspectives about MERs

Human teachers have long been using different representational techniques to present information to students, such as text, diagrams, practical demonstrations, abstract models or semi-abstract simulations (van Someren, Reimann, Boshuizen, & de Jong, 1998). Only very recently have researchers begun to look at the functions of multiple external representations (MERs) from new computational perspectives (e.g., Ainsworth, 1999). These MERs, as some researchers claimed, can support student learning by providing complementary ideas and processes, by constraining interpretations or by promoting a deeper understanding of concepts but not without new costs and challenges (Ainsworth, 1999)(see Figure 2). The major cost of learning with MERs is the difficulty in translating between different representations (e.g., Ainsworth, Bibby, & Wood, 1997).

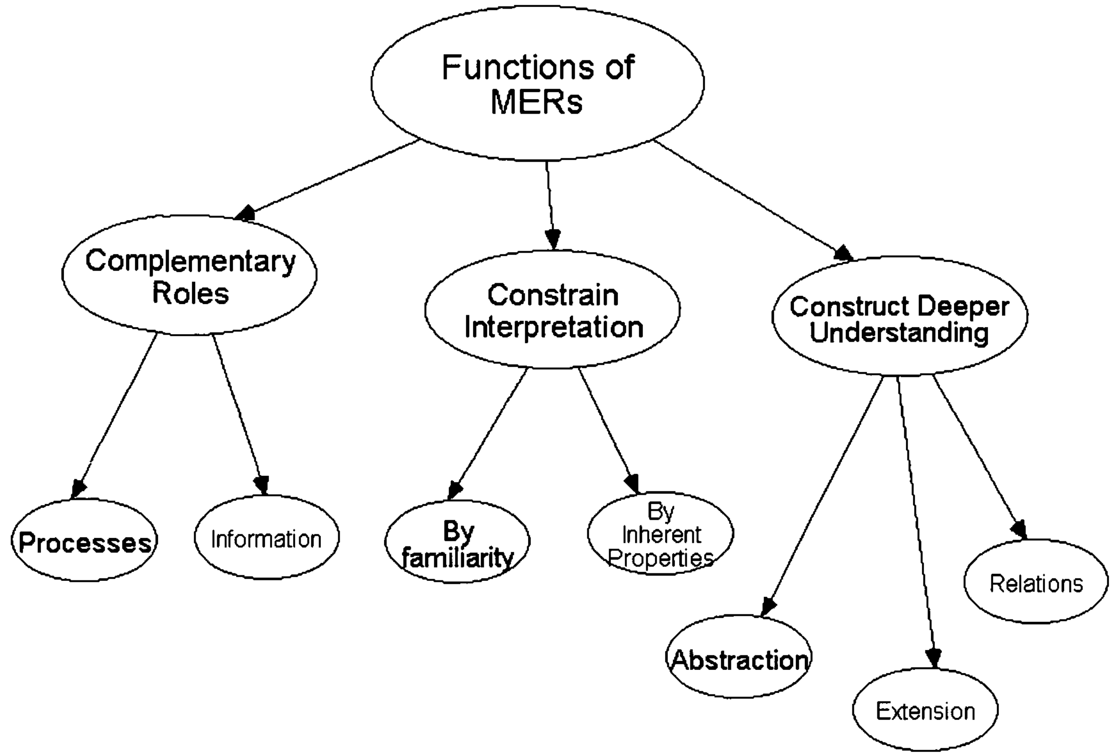

Figure 2 A simplified functional taxonomy of multiple external representations (MERs) (based on Ainsworth, 1999, p. 134 Figure 2)

Research Design and Procedures

Research Approach

An interpretive approach (Erickson, 1998; Gallagher, 1991) was used with a multiple-case embedded design (Merriam, 1998; Yin, 1994) using multiple data collection methods—online testing/surveying students, interviewing students and teachers, observing lessons/computer sessions and analysing documents/artefacts.

This study was the third of four case studies in a research project on genetics learning (see Tsui & Treagust, 2002; Tsui & Treagust, 2003a, 2003b). Quantitative and qualitative methods were combined for more meaningful interpretations of the case. As a naturalistic study, the teachers taught in an authentic classroom situation by integrating multimedia activities in their classroom teaching. The multimedia included *BioLogica,* a hypermodel (Horwitz & Tinker, 2001) for learning high school genetics, and other online multimedia, in particular those from the website "Your Genes, Your Health" (Cold Spring Harbour Laboratory, 2002). *BioLogica* enables students to manipulate processes at different, but dynamically related levels of life function and visualise the changes made (Concord Consortium, 2001).

Data Sources

Multiple sources of data were collected and generated: teacher and student semi-structured interviews and online pretests and posttests (that focused on genetics reasoning, gene conceptions, perceptions about student learning), computer log files (that tracked user interaction with *BioLogica*), classroom observation field notes and transcripts (based on field notes and audiotapes), researcher's journals and various documents (mined from the classroom and school).

The major source of data for this paper was from the semi-structured interviews and the online test data. The teachers and nine students were interviewed twice, before and after instruction. Seven peers of interviewees also took part in the second interviews to talk about their experiences in group presentations (see Figure 3). One student whose conceptions were most sophisticated was interviewed thrice.

School Context

The study took place in a private girls' school in the metropolitan Perth area of Western Australia. The school highlights academic excellence, independent learning and student confidence in using information and communication technologies (ICT). The Grade 10 students each owned a laptop computer connected to the Internet through the wireless networking within the school campus. The two participating science teachers, Ms Claire and Mrs Dawson (pseudonyms), had over 20 years of teaching experience and several years of using the laptops in their teaching in this school. Their teaching focused on both the Mendelian and molecular genetics including the developments of the latest gene technology in human genetics (see Figure 3).

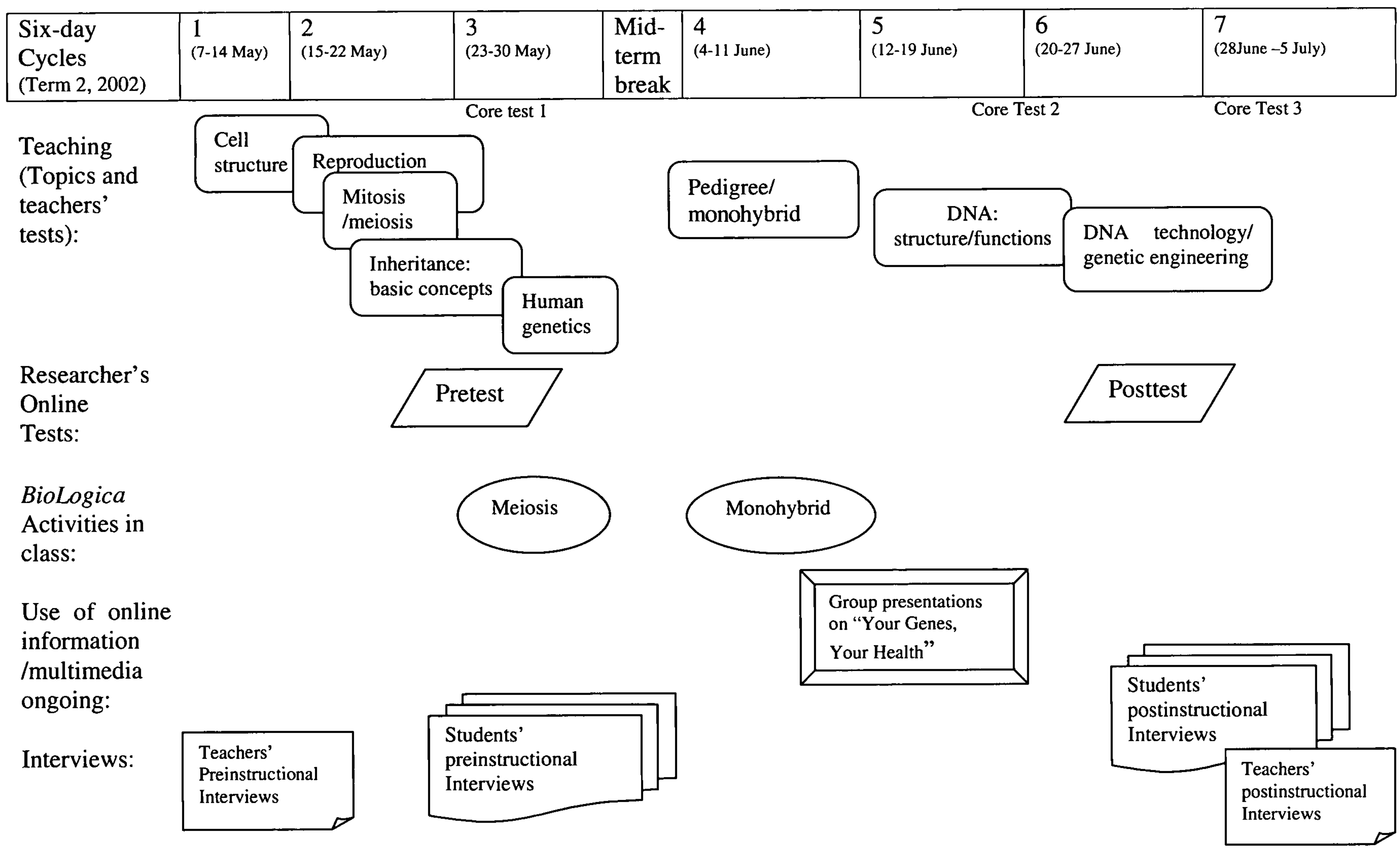

Figure 3 Teaching and research progress in Grade 10 Classes 1 and 2 in the laptop school. (Teaching progress and usage of *BioLogica* and other online multimedia were very similar in the two classes.)

Data collection, Analysis and Interpretation

The first author spent about nine weeks in the classrooms persistently observing most of Ms Claire and Mrs Dawson's lessons when genetics was being taught, conducting the interviews and collecting other data. All the interviews and five selected lessons were fully transcribed verbatim and teacher interview transcripts member-checked (Guba & Lincoln, 1989) by the teachers to increase the credibility of the data.

Students' conceptual learning was interpreted within Tyson et al.'s (1997) framework along the social/affective dimension (motivation and interest in interacting with MERs in multimedia they used), the epistemological dimension (genetics reasoning), and the ontological dimension (their conceptual change across ontological categories). We also adopted Thorley's (1990) status analysis categories in the analysis of the verbal data of the interviewee students.

The two authors had regular meetings to discuss the research progress with the second author acting as a debriefer. Like *member checking*, *peer debriefing* is one of the techniques used by the qualitative researcher to increase the credibility of the data being collected, analysed and interpreted (Guba & Lincoln, 1989). The analysis of the verbal data followed qualitative traditions (e.g., Merriam, 1998; Miles & Huberman, 1994), aided by the computer software tools *NUD*IST*[2] and *NVivo*[3]

Summary of Findings

The findings of this study are based on analysis and interpretations of data from multiple sources using Miles and Huberman's (1994) methods—matrices, graphs, charts and networks—to display the massive data in searching for regularities and patterns for generating assertions and drawing conclusions. The findings based on the major assertions are summarised in the following sections with quotes from interviews and some data displays to illustrate the analyses and interpretations in drawing the conclusions:

[2] NUD*IST (Non-numerical Unstructured Data Indexing, Searching and Theorising) is a software tool for analysing verbal data (Gahan, 1998).

[3] NVivo is the latest version of NUD*IST software (Gibbs, 2002)

Affective Conceptual Change

BioLogica: a New Opportunity for Students with Diverse Learning Styles

Both the teachers, Ms Claire and Mrs Dawson, held a belief that to the extent of providing opportunities to accommodate the diversity of learning styles of students, the *BioLogica* program was but one example of such new opportunity. Therefore they did not intend to use the program more often than using other resources to cater for the differing interests and learning styles of their students. Before instruction, Ms Claire had the following expectations about using *BioLogica* in teaching:

> It [*BioLogica*] will help some more than others. I mean there's some of the girls don't like using computers, and there's others that do like doing games and then they...probably would enjoy it, though we have to remember that we've all got different learning styles as well. And as I say, that's why we try to provide a range, and encourage the students that perhaps are at their main learning style as well as to develop different thinking skills. (Ms Claire/preinstructional Interview/13 May 2002)

Mrs Dawson also had similar ideas as she said:

> Oh, I think, um, all sorts of students have different styles of learning, different intelligences... I guess if it's just that we're encouraged to use different styles of teaching, because different students have different learning, um intelligences.
>
> (Mrs Dawson/preinstructional Interview/15 May 2002)

Based on the interview discourse, we believe that the teachers used a referent similar to the notion of Gardner's (1993) multiple intelligences in their classroom teaching.

After instruction, the student outcomes generally lived up to their expectations when Ms Claire told the first author in the interview:

> I think it [*BioLogica*] was just another avenue that they could see, and get another visual representation of it. I don't think, if they hadn't used *BioLogica* that they wouldn't still know what they know now at the end of it. I don't think it's made any of them know any more or any less. I think it's just been another resource that has helped some of them in their learning. And that's instant feedback changing the Dragons. (Ms Claire/ postinstructional Interview/4 July 2002)

Like the three teachers in the other case studies, Ms Claire identified two salient features in *BioLogica* (see Figure 4)—visualisation and instant feedback—that constituted the situational interests which interacted with the personal interests (Krapp, Hidi, & Renninger, 1992) of students to evoke in them some intrinsic motivations (Malone & Lepper, 1987) (Tsui & Treagust, 2002). However, the girls in this laptop school were not specifically interested in the *BioLogica* Dragons.

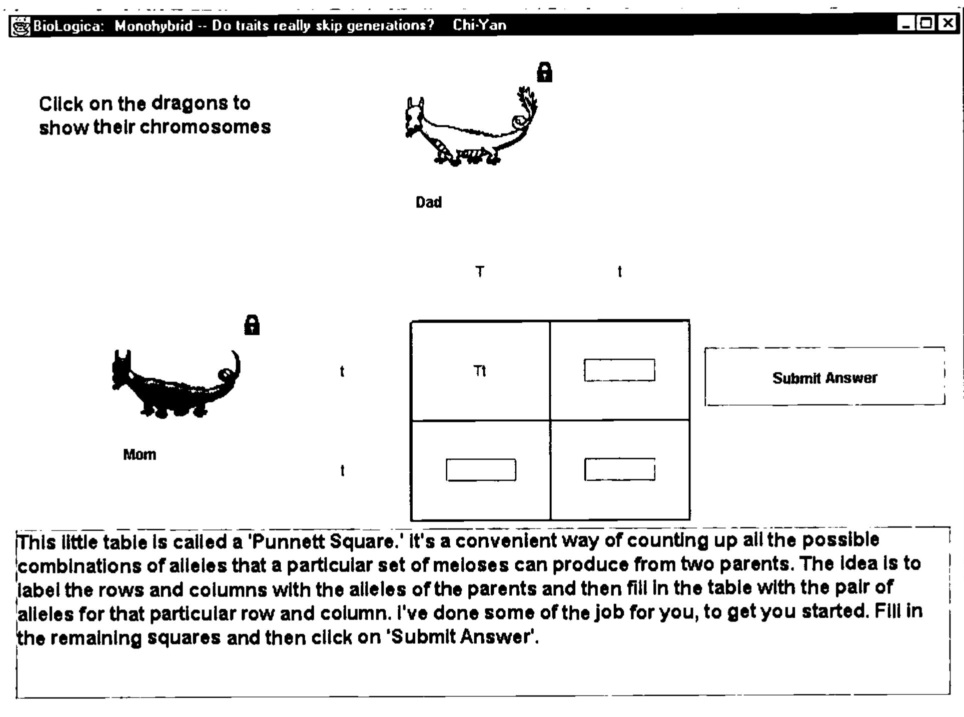

Figure 4 A snapshot of *BioLogica* activity 'Monohybrid' with an interactive Punnett square window dynamically linked to the Dragons' phenotype and genotype.

Students did Not Use BioLogica as Often as Expected

Although the students had unlimited access to their own laptop computers, their usage of the *BioLogica* activities—based on observational data and their online self-reports—was lower than expected as they also used other online multimedia on molecular and human genetics.

The teachers organised two *BioLogica* activities ('Meiosis' and 'Monohybrid') in class (see Figure 3) and suggested that they use several others after class. To find out how often and how many activities the students had done, one open-ended questionnaire in the online posttest asked them to self-report their usage by choosing the activities from a list[4]. The results revealed that only 65% of students in Class 1 and 60% in class 2 did the *BioLogica* activity 'Meiosis' and 59% and 60% did 'Monohybrid'. The other three more popular activities completed by the students were 'Horn Dilemma', 'Mutations' and "Mutation Inheritance." Some students never did any activities. As we will argue later in this paper, the type of multimedia and *BioLogica* activities used by the students might have affected their genetics reasoning or epistemological conceptual change.

Enjoyment in Learning with BioLogica and / or "Your genes, your health"

With their laptops, most students were highly motivated and enjoyed learning with *BioLogica* and online multimedia, particularly those from "Your Genes, Your Health" website (Cold Spring Harbour Laboratory, 2002) (see Figure 5).

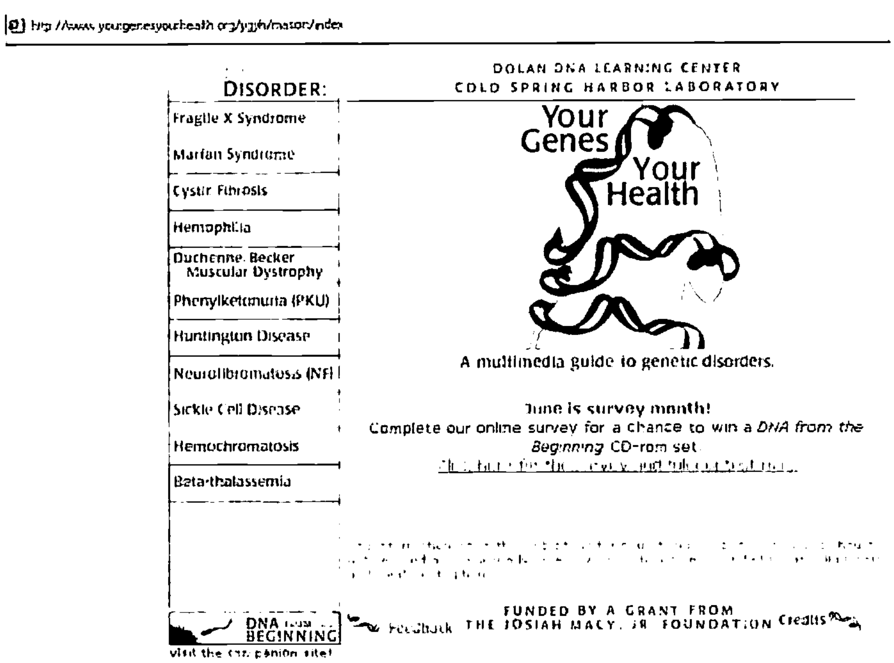

Figure 5 A screen shot of the home page of "Your Genes, Your Health" website about common human genetic disorders and the associated issues

[4] There are altogether 11 activities in BioLogica of which the teachers organised two in class ('Meiosis' and 'Monohybrid') and recommended them do another three ('Introduction', 'Inheritance' and 'Mutations') after class.

Analyses of the online questionnaire responses indicated that over half of them might have enjoyed using the web-based multimedia on human and molecular genetics more than *BioLogica* activities (see Figure 6) so that they did not use *BioLogica* as often as expected.

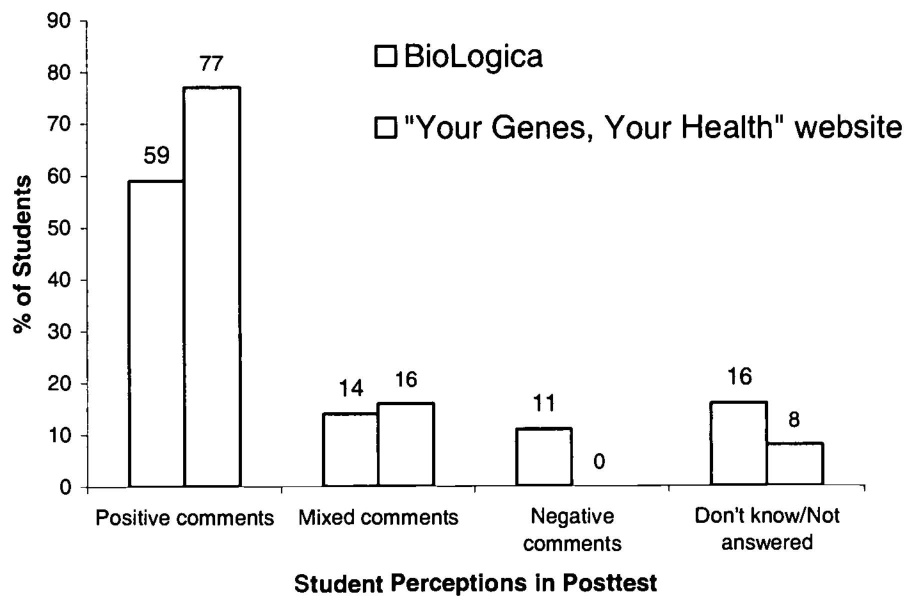

Figure 6. Comparison of student perceptions of *BioLogica* program and other "Your Genes, Your Health" website.

After instruction, Ms Claire's comment about some of the students' preferences was similar to our interpretation based on Figure 6. She said:

> A lot of them have said to me that they prefer the real-life stuff, and they see that [*BioLogica* activities] as sort of games and pretend, and they prefer the real-life genetics.
>
> (Ms Claire/ postinstructional Interview/4 July 2002)

Students enjoyed their learning with interactive multimedia. We therefore conclude that most students did display conceptual change along the social/affective dimension in terms their motivational outcomes.

Epistemological Conceptual Change

Most students improved their genetics reasoning but did not fare better than expected for this laptop school where each student owned her laptop computer and had unlimited access to the *BioLogica* activities and other online multimedia.

Most students improved their genetics reasoning, particularly in the easier types (Types I and III) and in a pattern similar to the results of Grade 10 students in another non-lap top school (see Tsui & Treagust, 2003a) (see Figure 7).

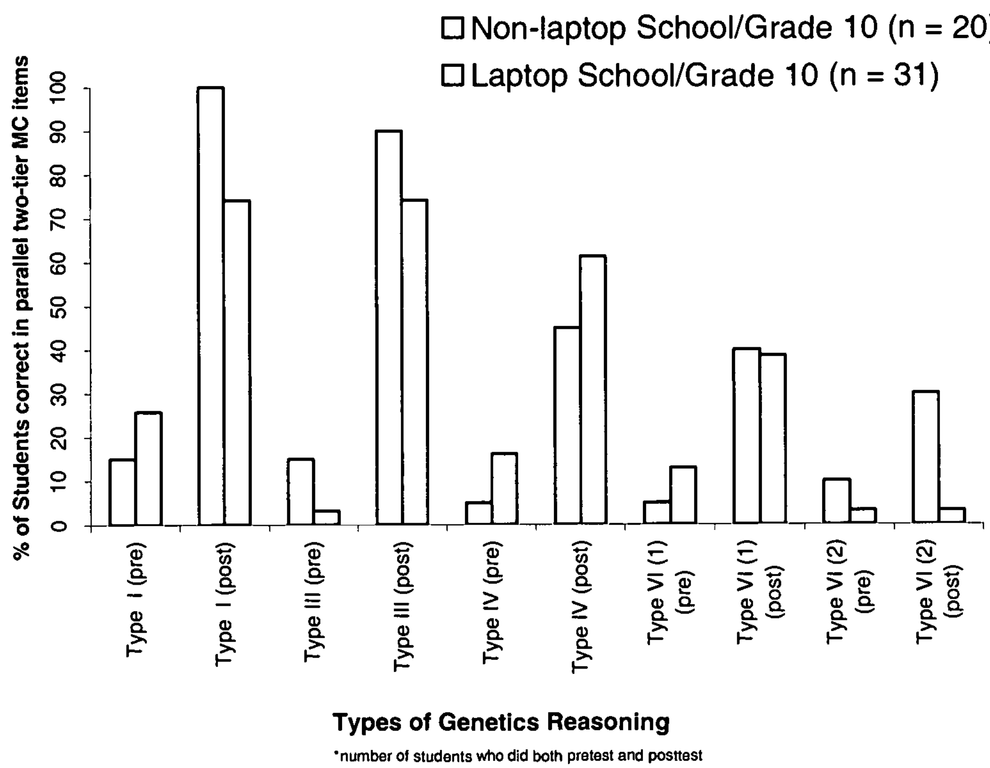

Figure 7. Comparison of genetics reasoning of students in the laptop schools and another non-laptop school (Only those students who took both pretest and posttest were included.)

As can be seen from Figure 7, Grade 10 students (n = 31)[5] in this laptop school and Grade 10 students (n = 20)[6] in another non-laptop case school had similar prior knowledge. Their improvement in genetics reasoning was similar despite the fact that the students in the laptop school were engaged more often in interactions with

[5] Only 31 of the 48 participants in this study took both online pretest and posttest.

[6] Only 20 of 24 Grade 10 participants in the non-laptop school took both online pretest and posttest.

multiple external representations (MERs) from *BioLogica* and other online multimedia about human and molecular genetics

Ontological Conceptual Change

Most students' ontological conceptual change was within the category of matter—gene as an inactive particle (an entity passed from the parents) to an active particle (an entity that determines a characteristic) (see Table 3). According to Venville and Treagust's (1998) framework, most students' conceptions were only intelligible-plausible (IP) .

Table 3

Students' Preinstructional-postinstructional Change in their Gene Conceptions based on an Open-Ended Online Questionnaire "What do you know about the gene?"

Gene conception	Number of Students (%)[a]	
	Pretest (*n*=42)	Posttest (*n*=37)
A gene is from parents/grandparents	25 (61)	15(41)
A gene determines a trait / characteristic	22 (54)	16(43)
A gene is /part of a chromosome	0 (0)	16(43)
A gene is / part of DNA	14 (34)	14 (38)
A gene is information	1 (2)	3 (8)

[a] Each student may hold more than one conception

When interview data were analysed we found that some high-achievers displayed radical conceptual change across ontological categories (from matter to process) when they conceptualised the gene as a productive sequence of instructions. Their conceptions were considered as intelligible-plausible-fruitful (IPF) (Venville & Treagust, 1998). Here, we portray the conceptual change of Andrea (pseudonym), one of the high-achievers among the interviewees in Ms Claire's class. Before instruction, she had the following dialogue with the first author:

Interviewer: So what do you know about genes now?

Andrea: Um, well we've just been learning about the chromosomes and how they make up the characteristics of the physical features and stuff.

....

Interviewer: So what do you think a gene does?

Andrea: A gene? Um, I think it's like, the plans for your characteristics and it tells what each cell should do and stuff.

Interviewer: How do your genes control those characteristics? Any ideas?

Andrea: Um, I don't know. I just heard that it's in the nucleus and then the nucleus passes it on to the rest of the cell and, yeah.

(Andrea/Preinstructional interview/24 May 2002)

In the first postinstructional interview on 28 June 2002, the first author asked Andrea again the similar questions:

Interviewer: What do genes do in the body?

Andrea: Oh. Um. Well genes are made up of the genetic code in the DNA, which tells the body to make proteins, and um, um they just carry the information which tells the body how it should work and stuff and how it should develop.

Interviewer: How does the information control all the development and so on?

Andrea: Um. Well each gene um, consists of genetic code which is used to produce proteins.

(Andrea/First postinstructional interview/28 June 2002)

Andrea's conceptions or mental models of the gene had changed along an ontological progression pathway (Venville & Treagust, 1998) towards being intelligible-plausible-fruitful (IPF) as shown in Figure 8.

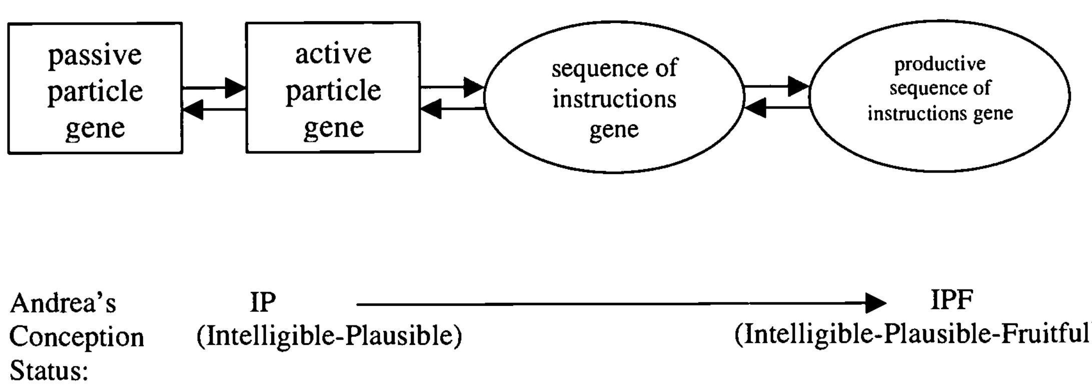

Figure 8. Ontological progression in Andrea's conceptions of the gene (Adapted from Venville & Treagust, 1998, p. 1049).

To confirm that Andrea's conception was intelligible-plausible-fruitful, the first author had a brief second postinstructional interview with her and found that her ideas were consistent with those in the first postinstructional interview.

We then analysed Andrea's ideas in the first postinstructional interview transcripts using Thorley's (1990) status analysis categories. We again found that her conception was intelligible-plausible-fruitful (IPF) as her ideas can be mapped to Thorley's fruitfulness status elements POWER and PROMISE. When asked to comment on a newspaper clipping about genetics, she said:

> "Ah. We understand much more about [this], because they're talking about genes, and you know what genes are now. Like, 'cause they're talking about DNA and everything so we know now why" (Andrea/First postinstructional interview/28 June 2002)

Furthermore, in the online test Andrea self-reported that she had completed six activities—'Introduction', 'Meiosis', 'Horn Dilemma' 'Monohybrid', 'Mutations', 'Mutation Inheritance' She also said that she enjoyed learning with *BioLogica* and believed that the activities helped her learning:

> It [*BioLogica*] worked well for me, 'cause I closed down everything else before I used *BioLogica*. So it worked fast. And it was good because you know, you get to, like actually play around with genetics and stuff and make your dragons and everything.
>
> (Andrea/First postinstructionl interview/28 June 2002)

We believe that Andrea was one of the high-achievers in this laptop school who displayed three-dimensional conceptual change (Tyson et al., 1997).

Nevertheless, the low-achieving students did not make much improvement in genetics reasoning and appeared to have less interest and motivation in learning with *BioLogica*. In brief, they did not experience any ontological change.

Conceptual Learning with MERs

As discussed in a preceding section, students in this laptop school had similar conceptual change along the epistemological dimension compared to the Grade 10 students in another non-laptop case school who had limited access to computers.

While students in both schools had similar preinstructional-postinstructional gains in genetics reasoning, students in this laptop school had more ontologically sophisticated gene conceptions (Venville & Treagust, 1998). The major factors for this difference appeared to be related to the curriculum, the teachers' teaching and their unlimited access to ICT via their laptop computers. Nonetheless, we believe that the teachers in this study did not fully harness the constraining function of the MERs in *BioLogica* for developing genetics reasoning but used them alongside other MERs in online multimedia to provide complementary information and processes for students to construct deeper understanding of the functions of gene or DNA—the other two functions of MERs (Ainsworth, 1999).

Although the findings in this study were unique because of students' ownership and portability in learning with laptop computers, some limitations must be considered when interpreting the findings. First, the students did not use *BioLogica* as often as other online resources on human and molecular genetics so that the contribution of the *BioLogica* MERs to their learning was not as significant as expected. Second, we were unable to collect enough log files for analysing the students' interaction with the MERs of *BioLogica* as we did in other case schools.

One unanswered question in this study was that low-achievers did not appear to have much conceptual change despite their engagement in learning with MERs. Although we did not have enough evidence to suggest how the teachers could have better scaffolded these students to learn better, this unanswered question did inform us to explore the issue of supporting the learning of low-achievers in the next case study.

Conclusions

Despite the limitations discussed in the preceding section, it can be concluded that the findings in this study indicate that learning outcomes of students appeared to be consistent with their prior knowledge, personal interest, motivation, the teachers' actions in teaching genetics, the classroom discourse, and the kind of multimedia they used most often in their learning.

In Stolarchunk and Fisher's (2001) study of 14 independent laptop schools across four Australian states, their qualitative data strongly supported that the use of laptop computers in learning science did not help to increase student cognitive achievement when compared with non-laptop students. As such, it is not surprising to find that student learning outcomes in a laptop school and a non-lap top school were similar. However, we believe that the students in this laptop school developed a deeper understanding of the conception of gene/DNA through their interaction with the multiple representations of genetics—*BioLogica* or other online multimedia.

In Australia, the Queensland personal computer project in 1992 promised to make Australia a more clever country (Rowe, 1993). Over the decade that followed, learning of science had not improved. A report (DETYA, 2001) about the status and quality of science education painted a disappointing picture of science education in Australian schools despite the fact that schools are now equipped with increasingly versatile computers. As researchers in science education, we may need to rethink about the meaning of the "catch-all phrase 'technology supports learning'" (DETYA, 2000, p. 303). Although interactive computer programs that feature MERs may hold promise in providing new opportunities for classroom learning, we believe that teachers' role remains a critical determinant of how technology can support conceptual change learning.

Acknowledgements

We wish to thank Dr Paul Horwitz of the Concord Consortium of the USA for granting us permission to use *BioLogica* for research in Australian schools. We are also grateful to the two participating teachers, the participating students, and the staff in the laptop school, who gave us support and help during our study there.

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.

Chi, M. T. H., Slotta, J. D., & de Leeuw, N. (1994). From things to processes: A theory of conceptual change for learning science concepts. *Learning and Instruction, 4*, 27-43.

Cold Spring Harbour Laboratory. (2002). *Your Genes, Your Health* [Onlinie multimedia]. Dolan DNA Learning Center. Retrieved 14 August 2002, 2002, from the World Wide Web: http://www.ygyh.org/

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

Concord Consortium. (2002, October). *BioLogica guide* [PDF File]. Concord Consortium. Retrieved June, 2002, from the World Wide Web: http://mac.concord.org/downloads/

DETYA. (2000). *The impact of educational research: Research evaluation programme*. Canberra, Australia: Department of Education, Training and Youth Affairs.

DETYA. (2001). *The status and quality of teaching and learning of science in Australian schools*. Melbourne, Australia: The Department of Education, Training and Youth Affairs.

Erickson, F. (1998). Qualitative research methods for science education. In B. J. Fraser, & K. G. Tobin (Eds.), *International handbook of science education* (pp. 1115-1173). Dordrecht, The Netherlands: Kluwer.

Gahan, C. (1998). *Doing qualitative research using QSR NUD.IST*. London: Sage.

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.

Gardner, H. (1993). *Multiple intelligences: The theory in practice*. New York: Basic Books.

Gibbs, G. R. (2002). *Qualitative data analysis: Exploration with NVivo*. Buckingham; Philadelphia: Open University Press.

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

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.

Harrison, A., & Treagust, D. (2001). Conceptual change using multiple interpretive perspectives: Two cases studies in secondary school chemistry. *Instructional Science, 29*, 45-85.

Hewson, P., & Lemberger, J. (2000). Status as the hallmark of conceptual learning. In R. Millar, J. Leach, & J. Osborne (Eds.), *Improving science education: The contribution of research* (pp. 110-125). Buckingham UK; Philadelphia, PA: Open University Press.

Hewson, P. W. (1981). A conceptual change approach to learning science. *European Journal of Science Education, 3*(4), 383-396.

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.

Horwitz, P., & Tinker, R. (2001). Pedagogica to the rescue: A short history of hypermodels. *Concord Newsletter, 5*(1), 1-4.

Johnstone, A. H., & Mahmoud, N. A. (1980). Isolating topics of high perceived difficulty in school biology. *Journal of Biological Education, 12*(2), 163-166.

Kindfield, A. C. H. (1992, March). *Teaching genetics: Recommendations and research.* Paper presented at the Teaching Genetics: Recommendations and Research Proceedings of a National Conference, Cambridge, Massachusetts, USA.

Krapp, A., Hidi, S., & Renninger, K. A. (1992). Interest, learning and development. In K. A. Renninger, S. Hidi, & A. Krapp (Eds.), *The role of interest in* *learning and development* (pp. 3-25). Hillsdale, NJ: Lawrence Erlbaum Associates.

Malone, T. W., & Lepper, M. R. (1987). Making learning fun: A taxonomy of intrinsic motivations for learning. In R. Snow, & M. Farr (Eds.), *Aptitude, learning, and instruction: Vol. 3 Cognitive and affective process analyses* (pp. 223-253). Hillsdale, NJ: Erlbaum.

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

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook* (Second ed.). Thousand Oaks, CA: Sage.

Pintrich, P. R., Marx, R. W., & Boyle, R. A. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research, 63*(2), 167-199.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66*(2), 211-227.

Rowe, H. A. H. (1993). *Learning with personal computers: Issues, observations and perspectives*. Hawthorne, Australia: Australian Council for Educational Research.

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

Stolarchuk, E., & Fisher, D. (2001). First years of laptops in science classrooms results in more learning about computers than science. *Issues in Eduational Research, 11*(1), 25-39.

Thorley, N. R. (1990). *The role of the conceptual change model in the interpretation of classroom interactions*. Unpublished doctoral dissertation, University of Wisconsin-Madison, Wisconsin, USA.

Tsui, C.-Y., & Treagust, D. F. (2002, April). *Social/affective dimension in learning genetics with multiple representations in secondary biology*. Paper presented at the annual meeting of the National Association for Research in Science Teaching (NARST), New Orleans, USA.

Tsui, C.-Y., & Treagust, D. F. (2003a). Genetics reasoning with multiple external representations. *Research in Science Education, 33*(1), 111-135.

Tsui, C.-Y., & Treagust, D. F. (2003b). Learning with computer dragons. *Journal of Biological Education, 37*(2), 96-98.

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

van Someren, M. W., Reimann, P., Boshuizen, H. P. A., & de Jong, T. (Eds.). (1998). *Learning with multiple representations*. London: Pergamon.

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.

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

Yin, R. K. (1994). *Case study research: Design and methods*. Thousand Oaks, CA: Sage.

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