A Constructivist Perspective on Monitoring Classroom Learning Environments Under Transformation

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Abstract

The original Constructivist Learning Environment Survey (CLES) was designed to enable teacher-researchers to monitor their development of innovative constructivist approaches to teaching school science. However, our research revealed major socio-cultural constraints to the development of constructivist learning environments. By incorporating a critical theory perspective on the socio-cultural framing of the classroom learning environment, we hoped that the revised CLES would empower teachers to address these constraints. This paper presents the results of two studies ‹ an action research study and a large-scale survey ‹ that examined the viability of the new CLES scales for use in school science classrooms. The results provide unique insights into a classroom environment under epistemological transformation, and raise important issues about the use of learning environment surveys to stimulate and monitor the

process of constructivist reform in school science. On the basis of these studies, we prodocued a refined form of the Student Perceived version of the new CLES.

Introduction

In 1994, we presented a new version of the Constructivist Learning Environment Survey (CLES) that we had designed to enable teacher-researchers to monitor their development of constructivist approaches to teaching school science and mathematics (Taylor, Fraser & White, 1994). Our ongoing research program had revealed major socio-cultural constraints (e.g., teachers acting in accordance with repressive cultural myths of *cold reason* and *hard control*) that worked in concert to counter the development of constructivist learning environments (Taylor, 1992, 1993, 1993 Nov). By incorporating a *critical theory* perspective on the socio-cultural framework of the classroom learning environment, we hoped that the new CLES would empower reform-minded teachers to address these constraints. As a result of that study, we made several changes to the format and structure of the original CLES (Taylor & Fraser, 1991).

The purpose of this paper is to present the results of two subsequent studies in which we examined the viability of the new CLES for monitoring the epistemology of school science classrooms. First, we conducted a *collaborative action research* study of two Grade 10 science classes in which the teacher (i.e., Vaille ‹ a coauthor of this paper) endeavoured to create a constructivist learning environment in which students reflect critically on their own values and beliefs about the ethics of human organ transplantation, share control with the teacher of key aspects of the management of their learning, and engage in meaningful and self-reflective discourse with fellow students. Second, we trialled the new CLES among 494 students in 41 science classes, in Grades 8 and 9, to determine its statistical integrity, especially the internal consistency and independence of each of the five scales.

In this paper, we present the results of the two studies which provide sound evidence of the viability of a refined version of the new CLES for monitoring constructivist reform in school science classrooms and raise important issues about learning environment surveys for monitoring processes of teacher-led epistemological reform.

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Critical Constructivism

The scales of the CLES were developed from the perspective of *critical constructivism* (Taylor, 1994a) which recognises that the cognitive constructive activity of the individual learner occurs within, and is constrained by, a socio-cultural context. The purpose of this social epistemology, which combines key elements of the *radical constructivist theory* of Ernst von Glasersfeld (1991) and the *critical social theory* of Jurgen Habermas (Habermas, 1978; McCarthy, 1985; Pusey, 1987), is to serve as a referent for the transformation of the socio-cultural reality of the science classroom environment.

Constructivism and critical theory provide unique and complimentary epistemological perspectives. Constructivism emphasises individual cognitive activity, but acknowledges negotiation with others as a means of determining the viability of knowledge. Critical theory emphasises the socio-cultural legitimation of knowledge, but argues for the emancipation of the individual from repressive cultural myths that constitute the social reality of legitimating institutions. Significantly, constructivism and critical theory share a non-foundational epistemological principle:
Because scientific knowledge arises from our attempts to impose order on our experiential worlds, scientific knowledge may have only a provisional (rather than absolute) status.

Critical constructivism is a social epistemology that challenges the fundamental tenets of institutionalised objectivism and the *technical rationality* of self-interest, individualism and exploitation that have governed much of the development of twentieth century modernity and contributed to a *legitimation crisis* in the profession of education (Schon, 1982). Most importantly, critical constructivism provides a powerful theoretical framework for understanding the cultural institution of modern science education and for setting an alternative agenda of establishing ethical communicative interactions amongst teachers and students in their endeavour to construct meaningful and viable scientific knowledge while resisting the enculturating imperatives of technical rationality.

Whereas constructivism has focused the attention of science educators on the sense-making processes of individual learners by highlighting the central role of prior knowledge, critical theory focuses our attention on the science classroom as a socio-cultural site that legitimates, often in subtle and unannounced ways, key aspects of the social learning environment. Critical theory draws to our attention the ways in which the social environment constrains the teacher and students to act in accordance with political agenda whose interests can be antithetical to good meaning-making and ethical social interactions. Whereas constructivism entails an *instrumentalist ethic* ‹ knowledge is valued because it works, or is viable ‹ critical theory challenges us to adopt a *discourse ethic* that values (self-) knowledge for its potential to enable us to communicate openly and richly, thereby realising the full potential of our species' most distinctive attribute.

Practical and Emancipatory Interests

Habermas's *practical* and *emancipatory* knowledge-constitutive interests arise from an ethical concern with organising social relations on the basis of communication that is free from what might seem to be natural constraint but which is, in reality, socially constructed domination, coercion and distortion associated with technical rationality. In the social sciences, the practical interest gives rise to hermeneutical, or interpretive, modes of inquiry that seek to understand the meaning-perspectives of actors in social situations.
In school science, the practical interest is concerned with establishing *open discourse* in which teacher and students act communicatively for the purpose of establishing rich mutual understanding. Conditions for open discourse include an atmosphere of trust and mutual respect and a commitment (by teacher and students) to disclose valued ideals and beliefs. However, a concern only with the practical interest can be disempowering to the extent that understanding is

framed by invisible ideologies rooted in historical taken-for-granted practices that perpetuate social injustices such as gender inequality, silencing of voices, and culturally exclusive practices.

The emancipatory interest is concerned with a *social turn*, that is, for making visible socio-cultural frameworks, especially repressive myths that 'cement' established social roles and practices. The means by which an emancipatory way of knowing and acting can be attained is *critical discourse* which purposively focuses attention on the (often implicit) validity claims that underpin the norms of social interactions. Two important principles of critical discourse in the science classroom are: (1) facilitating equality of opportunity for participation by avoiding/countering domination of more powerful others (including teacher and students); and (2) raising critical awareness of everyday ways of knowing and acting by examining critically normative social practices and their underpinning assumptions.

A classroom learning environment shaped by practical and emancipatory interests is, therefore, one in which a major emphasis is placed on facilitating students' involvement in active negotiation with teacher and peers. The object of negotiation is to make learning relevant to students' out-of-school lives (i.e., *lifeworlds*), encourage students to assume control of their learning, and to engender a critical awareness of shared cultural values and beliefs (e.g., reproductive nature of schooling, objectivist nature of knowledge, externalised control of assessment) that restrain constructivist reform of teaching and learning.

Trial Version of the New CLES

The version of the CLES that we used in our study of the two Grade 10 science classes ‹ a *Student Perceived Form*1 ‹ comprised 35 items arranged in five 7-item scales. This was a revised form of an earlier version that we trialled in a Grade 8 mathematics class in which the teacher endeavoured to create a constructivist learning environment (Taylor, Fraser & White, 1994). As a result of that study, we made the following revisions to the CLES for use in this study.

1. We worded positively nearly all items in order to avoid conceptually complex syntax associated with negative wording (and therefore greatly reduced the need to reverse-score item responses).
2. Associated with this strategy, we worded items to refer only to the presence of positive attributes of a constructivist learning environment, rather than use 'negative' (or conceptually asymmetric) items that refer to activities associated with non-constructivist learning environments (the responses to which would have been reverse-scored).
3. We used the prompt 'In this Biotechnology class. . .' throughout the CLES in order to focus students' thinking on their current (cf., past) learning environments.

Each of the CLES scales used in the Grade 10 science study was designed to obtain measures of students' perceptions of the frequency of occurrence of five key dimensions of a constructivist learning environment. Table 1 presents a sample item of each of the scales.

Personal Relevance Scale

In taking account of students' prior knowledge, we want teachers to broaden their pedagogical focus beyond students' abilities to recall accurately previously learned formulae, rules, and laws, and take account of the rich tapestry of experiences that students bring with them from their out-

of-school worlds. Consequently, the Personal Relevance scale is concerned with the connectedness of school science to students' out-of-school experiences. We are interested in teachers making use of students' everyday experiences as a meaningful context for the development of students' scientific knowledge.

Student Negotiation Scale

Although we recognise the importance of teacher-student negotiations, we wish to emphasise in the CLES the importance of developing instructional strategies that promote student-student negotiations as a central classroom activity. The Student Negotiation scale focuses on whether teachers' pedagogical attention extends beyond the traditional social activity of students helping each other to work out the correct answer to a problem. The scale assesses the extent to which opportunities exist for students to explain and justify to other students their newly developing ideas, to listen attentively and reflect on the viability of other students' ideas and, subsequently, to reflect self-critically on the viability of their own ideas.

Shared Control Scale

From a constructivist perspective, we are concerned that students have opportunities to develop as autonomous learners. We believe that this can be achieved partly by providing opportunities for students to exercise a degree of control over their learning that extends beyond the traditional practice of working 'independently' in class on sets of teacher-prescribed prescribed problems. The Shared Control scale is concerned with students being invited to share control with the teacher of the learning environment, including the articulation of their own learning goals, the design and management of their learning activities, and determining and applying assessment criteria. The rationale for this scale fits well with the notion of a *portfolio culture* (Duschl & Gitomar, 1991) that places a major emphasis on students evaluating their own conceptual development.

Critical Voice Scale

Of course, we realise that many teachers will feel constrained, at least in the short-term, by their externally-mandated interest in *delivering the curriculum* and *covering curriculum content.* This technical curriculum interest directs teachers' sense of accountability for curriculum implementation away from the classroom and towards external curriculum and assessment authorities. However, we believe that teachers also should be accountable to their students for their pedagogical actions. From a critical theory perspective, which promotes an interest in student empowerment, we would like teachers to demonstrate willingly to the class their pedagogical accountability by fostering students' critical attitudes towards the teaching and learning activities. The Critical Voice scale assesses the extent to which a social climate has been established in which students feel that it is legitimate and beneficial to question the teacher's pedagogical plans and methods, and to express concerns about any impediments to their learning.

Table 1
CLES Scales and Sample Items Used in the Grade 10 Science Study

CLES Scales	Sample Items *In this Biotechnology class.* . .
Personal Relevance: relevance of learning to students' lives.	(1) I learn about the world outside of school.
Critical Voice: legitimacy of expressing a critical opinion.	(3) It's OK to ask the teacher "why do we have to learn this?"
Shared Control: participation in planning, conduct and assessment of learning.	(4) I help the teacher to plan what I'm going to learn.
Uncertainty: provisional status of scientific knowledge.	(8) I learn that the views of science have changed over time.
Student Negotiation: involvement with other students in assessing viability of new ideas.	(23) I ask other students to explain their ideas.

Uncertainty Scale2
One of the major constraints to constructivist pedagogical reform is the popular myth that Western science is a universal, mono-cultural (or accultural) endeavour that provides accurate and certain knowledge of objective reality. The objectivist *myth of certainty* implies that scientific knowledge exists independently of collective human experience and that it has a privileged status. By contrast, we want teachers to provide opportunities for students to experience the inherent uncertainty and limitations of scientific knowledge. The Uncertainty Scale has been designed to assess the extent to which opportunities are provided for students to experience scientific knowledge as arising from theory-dependent inquiry, involving human experience and values, evolving and non-foundational, and culturally and socially determined.

Additional Attitude Scale

For the purpose of better understanding students' responses to the classroom learning environment, we included in this study an additional scale to assess students' attitudes towards their science class. Normally, the scale is not part of the CLES. The Attitude scale comprised items that asked students about their anticipation of the class, their sense of the worthwhileness of the class, and the impact of the class on their interest, enjoyment and understanding. The Attitude scale was based partly on items in the *Test of Science Related Attitudes* (TOSRA: Fraser, 1981).

Format and Scoring

Learning environment researchers have used a technique that enables teachers to readily hand-score the results of questionnaires administered to their own classes. Items are arranged in a cyclic format: items are groups such that the first item of each group belongs to the first scale, the second item of each group belongs to the second scale, and so on. This approach was adopted for the administration of the CLES to students in the Grade 10 science study. Table 2 shows the allocation of the 42 items of the questionnaire (35 CLES items, 5 Attitude Scale items).

The version of the CLES that we used in the Grade 10 science study had a 5-point Likert-type frequency response scale which comprises the categories: *Almost Always* (5 points), *Often* (4), *Sometimes* (3) *Seldom* (2), and *Almost Never* (1). Therefore, the maximum possible score of each 7-item scale was 35 and the minimum possible scale score was 7.

However, because Vaille's teaching approach deliberately eschewed formal summative assessment of students' learning outcomes, we excluded two assessment-related items of the Shared Control scale (i.e., item 28*: I have a say in deciding what will be on the test; item 40*: I have a say in deciding how my learning is assessed). For this 5-item scale the maximum possible score, therefore, was 25 and the minimum possible score was 5. The adjustment to the Shared Control scale resulted in a restriction in the range of scores for the scale, an outcome that has implications for comparative analysis of scale scores. The restricted range is indicated in the graphical presentation of results by changes in the maximum and minimum graphs and an alternative labelling of the y-axis (in parentheses) (see Figs 1 & 2).

Table 2
Allocation of Items to CLES and Attitude Scales
(7 items/scale)

CLES Scale	Item Numbers
Personal Relevance	1 7 13 19 25 <u>31</u> <u>37</u>
Uncertainty	2 8 14 20 26 32 <u>38</u>
Critical Voice	3 9 15 21 27 33 <u>39</u>
Shared Control	4 10 16 22 28* 34 40*
Student Negotiation	5 11 17 23 29 35 41
Attitude Scale	6 12 18 24 <u>30</u> <u>36</u> <u>42</u>

Items without their item numbers underlined are scored 5, 4, 3, 2 and 1, respectively, for the responses Almost Always, Often, Sometimes, Seldom and Almost Never. Items with their item numbers underlined are scores in the reverse manner. Omitted or invalid responses are scored 3. Items 28*, 40* omitted from analysis of Grade 10 science study.

The Grade 10 Science Study

At the time of this study, Vaille was teaching science on a full-time basis in an independent all-girls secondary school in the Perth metropolitan area and was enrolled on a part-time basis in a 'Master of Science in Science Education' degree course at Curtin University. At school, Vaille was teaching a Biotechnology course that she had designed as part of a compulsory Grade 10 course entitled 'Women and Technology'. In designing the Biotechnology course, Vaille had drawn on her experiences in an earlier career as a medical technology researcher to provide students with opportunities to examine important ethical issues associated with human organ and tissue transplantation policies and practices.

Critical Constructivist Pedagogy

Vaille had been influenced strongly by coursework that she had completed at Curtin University and decided to reshape the pedagogy of her Biotechnology course in accordance with key principles of constructivism and critical theory. The goal of her reconstructed pedagogy was to enable students to articulate and evaluate their established ethical values and beliefs by engaging in critical self-reflective thinking, rather than to memorise factual information for end-of-course assessment. In order to help achieve this goal, Vaille formally severed the relationship between learning and summative assessment by abandoning end-of-course grading. Vaille's emancipatory interest also caused her to consider ways of reducing the power differential between herself and students. She committed herself to establishing with students a 'caring and sharing' relationship, rather than a relationship defined in terms of powerful teacher and powerless students. Vaille reported how she endeavoured to shape her classroom learning environment in accordance with these pedagogical ideals:

The students and I interacted as a seminar group on a relatively equal footing rather than as a 'powerful teacher' and 'powerless pupils'. Firstly, the importance of students' prior knowledge and values was acknowledged by listening to and accepting students' views on transplantation. Secondly, students had ample opportunities to discuss, debate, and reflect on their existing and developing understandings and values through discussion with the teacher and their peers. This cooperative learning environment provided opportunities for students to clarify, question and modify their own belief systems. Both planned and unplanned discussions occurred, and I preferred to deflect questions back to students rather than supply a direct answer. Video segments, written case studies, and role play were used to stimulate debate. (Dawson, 1994, p. 19)

Collaborative Action Research

For her dissertation, Vaille adopted an *action research* approach and focused her study on the efficacy of her constructivist teaching innovations in the Biotechnology course. Action research involves teachers in becoming researchers in their own classrooms and addressing problems of immediate practical significance to their teaching (Grundy, 1987; Kemmis & McNiff, 1993; McTaggert, 1991). Vaille decided to investigate the impact of her constructivist teaching strategies on students' attitudes and on their abilities to clarify, reflect critically on, and modify

their understandings of ethical issues associated with transplantation. At the end of the year, Vaille presented a dissertation on her action research study (Dawson, 1994) which was examined by a third party who had no involvement in any aspect of the study (and who awarded the report a high distinction grade).

Another member of the research team (Peter), who served as Vaille's research supervisor, collaborated with her in the role of co-researcher. Collaborative classroom based research is well-recognised for the benefits that can acccrue to both educational research and teaching practice (Kyle & McCutcheon, 1984; Saphier, 1982; Shymansky & Kyle, 1991; Watt & Watt, 1982). What is less-well documented are the dilemmas that can arise from performing these sometimes conflicting dual roles (Taylor, 1994b; White, 1994). The collaboration between Vaille and Peter broadened the research agenda by including the CLES as an additional method of generating research data. In the context of this paper, the research question that framed the generation and analysis of data occurred within an interpretive case study framework (Erickson, 1986) and asked:

To what extent can the CLES provide a plausible perspective on a constructivist classroom learning environment for school science?

Data Generation and Analysis

In writing this paper, we generated data from multiple sources both during the course of the study and as we reflected retrospectively on the data and on our individual and collective experiences.

Vaille's perspective was elicited from: (1) extracts of the personal journal that she had maintained during her study; (2) the dissertation that she presented for her Masters degree (Dawson, 1994); and (3) her contribution to drafts of this paper. Students' perspectives were elicited from: (1) transcripts of interviews of selected students conducted both during and on completion of the 10-week course; (2) a video-recording of several lessons; (3) the results of a survey of perceived usefulness of teaching strategies administered on completion of the course; (4) the results of administering towards the end of the course four of the five scales of the CLES, together with an additional attitude scale; and (5) transcribed recordings of some of the research team's discussions.

Rigor and Ethics

We attempted to optimise the *plausibility* of the results of the study by means of the strategy of *triangulating* data (Denzin, 1988) from multiple sources. As we analysed the data and developed interpretive assertions, we purposively sought *disconfirming evidence* and examined discrepant cases. For example, as well as focusing our analysis on several students in Class C ‹ Julie, Alex, Susan ‹ who accepted readily Vaille's invitation to participate in transforming the classroom learning environment, we included Kirsti, one of four Class B students who seemed to feel uncomfortable with their new learning roles. We modified our assertions by taking into account the full range of students' perspectives and actions. Fig 2 displays questionnaire results of two

students with widely differing attitudes and classroom learning environment perceptions (i.e, Alex and Kirsti).

Permission was sought formally from parents for the participation in the study of their daughters. Vaille explained to students the purpose and nature of her study but, because of logistical problems, could not allow students the option of transferring to a Grade 10 Biotechnology class that was not involved in her study. All information obtained from individual students (i.e., questionnaires, interviews) was recorded with consent. In reports on the study, the name of the school has been ommitted and students have been given pseudonyms to protect their identities. Vaille decided that she wished to be identified as a full participant in the study and to have her real name published in reports on the study.

Results

The results of the Grade 10 science study are expressed in the form of interpretive *assertions* which constitute emergent theory grounded in empirical data (Erickson, 1986). Evidentiary warrants for each of the assertions are presented below.

Assertion 1 When combined with data from other sources, the CLES can provide plausible accounts of constructivist learning environments in school science.

Assertion 2 In a classroom under epistemological transformation, multiple and conflicting learning environments can coexist as different students embrace or reject epistemological change. Teaching strategies aimed at creating learning environments for empowering students (eg., critical voice, shared control) can be counter-productive for students who prefer more teacher-centred learning environments.

Table 3 shows the results of the questionnaire (4 CLES scales, 1 attitude scale) for each of Classes B and C. These results have been displayed graphically in Fig 1, from which it is apparent that the two classes had generally positive learning environment perceptions. The two classes recorded almost identical positive perceptions on two key dimensions of the learning environment (i.e., *personal relevance, critical voice*). However, the learning environments of the two classes differed in other respects (i.e., *shared control, student negotiation*). Overall, Class C students perceived a more positive learning environment and reported a generally more favourable attitude towards lessons.

Measures of the perceptions and attitudes of two students ‹ Kirsti and Alex ‹ are presented in Table 4 and displayed in Fig 2. Alex represents the majority of conforming students, especially in Class C, who reported positive learning experiences and favourable attitudes. Kirsti was one of the four dissident students of Class B who reported a much less favourable attitude and less positive learning experiences.

Table 3
Descriptive Statistics of CLES Scales and Attitude Scale for Classes B & C

	Class B (N=9)		Class C (N=10)	
Scale	Mean Score	Standard Deviation	Mean Score	Standard Deviation
Attitude	22.1	4.8	25.8	4.3
Personal Relevance	25.6	5.2	26.5	4.8
Critical Voice	28.0	3.9	27.9	2.8
Shared Control	14.1	5.2	19.5	3.4
Student Negotiation	23.9	4.8	25.8	4.3

Personal Relevance

In both classes, most students perceived that what they were learning in class often was related directly to the world outside of school. Students' perceptions of the high degree of connectedness between classroom activities and the outside world is not surprising when one considers that one of Vaille's main goals was to engage students in thinking critically about their own (often implicit) views of the ethics of human organ transplantation which is a social issue that attracts much attention in the daily print and electronic media. Many of the learning activities were designed to 'bring the outside world into the classroom' and to challenge students to explore their own ethical beliefs as they considered the experiences and values of people involved directly in the practice of transplantation.

In response to a questionnaire that Vaille had designed to evaluate her teaching strategies, most students reported that amongst the most useful activities were role playing a hospital ethics committee and analysing by means of 'conflict mapping' video-recorded case studies of transplant recipients and donor families (Dawson, 1994). For example, consider the following extract of a student interview:
Vaille: The activity that we did today, which is a 'conflict map'. . . what did you think of that?
Julie: Yes, that was quite good, because you get to consider what the people are sort of going through at the time of the transplant. You sort of have to think about what the donor's family are feeling, and what the recipients are feeling. (Dawson, 1994, p. 38)

Figure 1. Learning environment perceptions and attitudes of Classes B and C

However, some students did not appreciate the relevance of activities such as class discussion that were designed to promote critical self-reflective thinking. Instead, they focused on the factual content of the course and complained that the course had not taught them much more than what they had not known already. For example, consider the following comments of Kirsti who was one of the group of four students in Class B with relatively unfavourable attitudes toward the class:

Kirsti: I think it's good to have like open discussions in this type of subject. But you don't need it in maths and science, as I said before, because what you're going to learn can't be changed by discussing it.
Peter: You didn't feel like you learned anything new?
Kirsti: [A]fter the first couple of lessons. . . . I felt we'd learnt it all. . . . [It was] general knowledge basically, and it was obvious.
(CLES Interview, p. 8)

Fig 2 indicates that Kirsti perceived her learning activities to be personally relevant only a little more than sometimes. She seemed unable to make sense of activities that involved class discussion, particulary when discussion involved the expression of students' opinions. For Kirsti, expressing personal opinions is an activity that detracts from the relevance of learning science. Learning science is relevant when she is involved in a fact-gathering activity that adds to her store of knowledge about the external world, rather than a discursive activity that challenges her to reflect critically on her scientific knowledge or on the usefulness of that knowledge in the social world beyond the classroom.

For teachers who wish to make learning science an activity that is directly related to the social world outside of the classroom, a major challenge lies in convincing students such as Kirsti that science is much more than a technical body of objective facts. The intersection of science and society provides teachers with a compelling context for enabling students to consider how scientific knowledge can challenge society's established views of ethical practices and how emergent ethical positions can, in turn, shape the conduct of science.

Table 4
Scale Scores of Selected Students

	Scale Scores				
Student	Attitude	Relevance	Voice	Control	Negotiation
Alex	33	32	33	19	30
Kirsti	20	23	31	11	23

Figure 2. Learning environment perceptions and attitudes of Alex and Kirsti

Student Negotiation

One of the main ways in which Vaille endeavoured to facilitate students expressing their own ideas in class was to create an empathetic and safe environment that encouraged students to disclose and discuss their feelings. Because of the sensitive nature of the topic, which was

heightened by some students' personal family involvements in organ transplantation, Vaille was assiduous in her attempts to establish and maintain social norms for a 'caring and sharing' classroom learning environment. This meant that, from time to time, she focussed discussion on the issue of appropriate rules of classroom discourse. Amongst these rules were 'respect for others' opinions' and 'tolerance of diversity of opinion'. It was Vaille's belief that these rules were essential for creating a learning environment in which students listened attentively to other students, expressed openly their own thoughts and feelings and, consequently, reflected self-critically on their own established ethical beliefs and values.

In Class C, students reported that the opportunity for negotiation with their peers occurred often (see Fig 1). From Vaille's perspective, students in this class became increasingly willing to share their private thoughts as they came to realise that their views would be listened to in an empathetic manner. In small group activities, such as role playing a hospital ethics committee whose task was to select and reject potential organ recipients (including children), these students generally expressed their feelings and ideas forcefully but constructively as they struggled to reach consensus on 'life and death' issues. The extent to which students in this class valued these experiences is encapsulated in the following extracts of Vaille's interview of two students:

Vaille: There has been quite a bit of discussion with other students. How do you find that?
Alex: Actually, at the start, when we were having our discussion I was thinking what I had to say: and then I heard all these different points of view which was really interesting.
Julie: [S]ometimes you don't think of everything, and you're sort of getting other people that sort of make you think 'Oh yes, why didn't I think of that?'. . . You sort of get to voice your own view more, which is sort of like philosophy where you talk a lot.
(Dawson, 1994, p. 56)

By contrast, Class B students perceived opportunities for negotiation with their peers to have occurred less frequently. Although some 'successful' negotiation took place in small groups, in the whole class forum students tended to talk *at* each other rather than *with* each other. This unreflective type of discourse originated from the four students with relatively unfavourable attitudes. They frequently punctuated whole-class discourse with disgruntled outbursts that had the effect of countering Vaille's attempts to create conditions for a caring and sharing atmosphere. Although they were keen to voice their opinions, the four students were unwilling to listen attentively to, or respect the views of, their peers. Kirsti admitted that, although frequent opportunities existed for negotiation with fellow students, to consider the views of other students was of little benefit to her because of her unwillingness to change her established mind-set:
Teacher: What about the discussion of other students? Does that have any effect on your own views?
Kirsti: Not really. Only like for me to argue against them . . .
Teacher: Is that because you already have made up your mind on what you think?
Kirsti: Yes, If my mind's set then I don't change my view of what we're talking about.
(Dawson, 1994, p. 40)

For students such as Kirsti, who do not attach much value to open discourse in science class and whose interest in science learning is shaped largely by a conception of adding to their individual

knowledge store, there is not much benefit to be gained in taking seriously the personal opinions of other students.

For teachers who wish to foster conditions for the type of open discourse that flourished in Vaille's Class C, the challenge is to persuade students such as Kirsti of the legitimacy of negotiation as a normal part of both science and learning science. In order to change their habituated discursive practices, students might need to be convinced that science, itself, is constituted by discourses, and that a rich understanding of science involves learning how to participate in a discourse of not only 'talking science' (i.e., the technical agenda) but also of 'talking about learning science'. In creating conditions for the meta-discourse of talking about learning science, teachers need to foster in students a need for mutual respect and understanding, and a need for constructive self-disclosure of their concerns about strange new ways of learning that involve collaboration with other students.

Shared Control

A major difference in the learning environments of the two classes was the extent to which students perceived that they shared control with Vaille of their learning activities. Figure 1 shows that, although Class C students perceived that they often (on the modified response scale) had opportunities to be involved in the classroom management of their own learning, the students of Class B perceived this to happen much less frequently. Although Vaille did not involve students in selecting the teaching strategies, as the course progressed she actively encouraged students to modify the manner in which teaching strategies were implemented.

For example, one of Vaille's teaching strategies involved students in the design of a questionnaire that they used subsequently to interview up to ten people about their views towards human organ transplantation. Not only was this activity designed to enable the students to reflect on and clarify their own views, but also it provided opportunities for students to accept responsibility for the management of their own learning. Vaille negotiated with the class about the size of their working groups and the time for completion of the activity. She also gave them opportunities in class to determine the content and length of their own questionnaires.

Because of Vaille's success in creating conditions for open discourse in Class C, students felt that they shared control with their teacher of the classroom learning environment, particulary in relation to assessing the success of their own learning. In Class C, students generally responded positively to opportunities for self-determination and, as the course progressed, engaged with increasing enthusiasm in interactive and self-reflective activities. The openness of the classroom learning environment for enabling students to disclose to Vaille their tentative understandings and the progress of their small-group projects is evident in the following extract of an interview about students' responses to the CLES.

Peter: [Item] Number 10: 'I help the teacher decide how well my learning is going'.
Alex: I said 'Almost Always'. . . because we just have a really open relationship with the class, so . . . you were able to tell [the teacher] if you were understanding things and, you know, how progress was going with your decisions.
(CLES Interview, p. 5)

By contrast, Vaille reported that the four dissident students of Class B were at their most restless during this type of activity. They did not respond positively to opportunities in class to manage positively their own learning. Indeed, they perceived a lack of opportunity to control their own learning. For example, Figure 2 shows that Kirsti perceived that she seldom had opportunities to control her own learning. Although Kirsti and her friends had the same opportunities for managing their own learning as other students, they were reluctant to do so. Although they conformed to Vaille's requirements for undertaking small-group activities, they did so begrudgingly and directed little creative energy or enthusiasm into their work. During whole-class discussions, they frequently seized the (counter-productive) opportunity to voice personal animosities with other students, action that probably is attributable to their dissatisfaction with unfamiliar teaching and learning roles and challenging classroom social dynamics. They seemed to respond most favourably when the goals of the lesson were relatively straightforward and explicit, that is, when the classroom approximated a 'normal' teacher-centred learning environment that offered them little direct control of their learning activities. These students may be likened to Belenky et al's. (19??) *separate knower* who views the teacher as a provider of external knowledge. When Vaille did not subscribe to their learning role expectations as passsive receivers of official knowledge they responded by rejecting her attempts to transform the classroom environment.

Teachers who wish to share control with their students of the classroom learning environment are likely to face a dilemma, especially when they wish to engage students in transforming the learning environment:
How to foster students' participation in creating a more student-centred learning environment without *imposing* the requirement on unwilling students?
Part of the solution might be to avoid sudden and dramatic change that is likely to threaten insecure students, especially students who already have a less than favourable predisposition towards science, the teacher, or the school, or whose epistemological mind-set is likely to militate against the demands of constructing new learning roles that require the seemingly perverse mix of increased autonomy and increased social accountability.

Critical Voice

The other similarity in the learning environment of the two classes was the common student perception that expressing a critical opinion about teaching and learning activities had a high degree of legitimacy (*critical voice scale*). Vaille deliberateley adopted a teaching role that, as the school term progressed, changed from provider of factual information (eg., biomedical technicalities of organ transplantation) to facilitator of students expressing their own ideas, especially in the forum of the whole class. In the latter role, she endeavoured to empower students by inviting them to provide critical commentary on the efficacy of her innovative teaching strategies and by showing respect for students' opinions by taking seriously their feelings and involving them in decisions about teaching strategies.

For example, after the first three weeks of the course, Vaille invited students to be critical of the usefulness of their personal journals. She had introduced this activity in an attempt to facilitate students' self-reflective thinking. Although a few students valued the activity, most students rejected it as lacking relevance to them. Vaille was faced with a dilemma. Although she believed

that this activity was potentially beneficial for students inasmuch as it would facilitate their self-reflective thinking by providing an *audit trail* of their conceptual development, she felt that it was better not to compell them to undertake such a highly unpopular activity. Consequently, she discontined the use of personal journals as a mandatory learning activity.

Although both classes had identical perceptions of the extent to which it was legitimate to express critical opinions of the learning environment, there was a distinct contrast between Classes B and C in the way in which students sought to express their critical voices. Class C students (who welcomed the teaching innovations) responded positively to opportunities to provide Vaille with constructive criticism about the impact on their learning of innovative teaching strategies. However, Vaille reported that these students tended to express their criticism in an almost apologetic manner. During an interview about students' responses to the CLES, it became apparent that some students who had had very positive learning experiences during the course felt very uncomfortable with the idea of expressing themselves in a way that might be interpreted as being critical of the teacher, especially when they did not believe that criticism was warranted:
Peter: The first question is: 'It's OK to ask the teacher 'Why do we have to learn this?".
Susan: I had 'seldom'. . . [because it] sounds like a very negative thing to say. . . . Everthing we did in the course was relevant to the topic we were doing, so she didn't go off on something else.
(CLES Interview, p. 3)

By contrast, Class B students were very willing to offer critical comments to Vaille about the efficacy of her innovative teaching strategies. For example, consider the following extract of an interview that Vaille conducted with Kirsti about the use of personal journals:
Vaille: Some of the activities that we've done so far, I just wanted to ask you what you thought about them. What about the personal journal?
Kirsti: It's pointless. . . . We don't even refer back to it. . . . I don't, and I don't think anybody else does. And we don't need it. What use has it got to us?
(Dawson, 1994, p. 44)

In the context of the classroom, the responses of Class B were dominated by the four students with unfavourable attitudes who exploited the opportunity of engaging in critical discourse to pursue their personal agendas by expressing animosity toward other students and 'testing' the limits of acceptable classroom behaviour. This unexpected response indicates the 'double-edged' nature of the 'sword' of student empowerment.

A challenge for teachers who wish to foster critical discourse in their science classes is, therefore, to harness the discourse in such a way that it focuses students' self-reflective critical thinking on the socio-cultural barriers that hinder their learning. For example, critical discourse might induce students to reflect self-critically on their understandings of the nature of science or on the implicit social norms that constrain their classroom roles as social learners. Used with care and respect, critical discourse might prove to be an invaluable means of desconstructing barriers to open discourse in which students' valued beliefs are disclosed and examined non-judgementally. It seems likely, however, that critical discourse can be potentially threatening, disruptive and divisive, and that students could benefit best from a gradual initiation. Some students are likely to need encouragement to be critical and others are likely to need to be

restrained. In both cases, the teacher should ensure that the legitimacy of critical discourse is understood to depend on mutually agreed social norms that govern its use; the 'bottom line' is to maintain a sharing and caring environment of mutual respect.

Plausibility of the CLES

The Grade 10 study provides compelling evidence of the viability of the CLES for providing a plausible perspective of a teacher's attempts to transform her classroom learning environment in accordance with a critical constructivist epistemology. By triangulating data from a variety of sources, including the teacher, selected students, and a collaborative researcher, we were able to formulate a grounded theory (i.e., Assertion 1) that signals the potential explanatory power of the CLES for other teacher-researcher studies that have a similar transformative agenda. In this study, the explanatory power of the CLES was evidenced by its ability to identify multiple learning environments within the one classroom. By focusing our analysis of CLES data on selected students, we were able to discriminate between the somewhat conflicting learning environments of students who embraced epistemological reform and those who tended to reject it (i.e., Assertion 2).

Refinements to the New Cles

In response to the results of the Grade 10 science study and an earlier Grade 8 mathematics study (Taylor, Fraser & White, 1994), we made a number of refinements to the new CLES. Of particular concern to us were the numerous complaints from students who perceived a repetitiveness amongs items of the CLES. Some students wrote critical comments next to CLES items; and other students, particularly those with less than favourable attitudes towards their teachers' constructivist reforms, either failed to respond to all items or resorted to selecting only the 'Sometimes' response category. Subsequent interviews with some of these students indicated a need for greater meaningfulness when completing the CLES.

It has been a tradition of learning environment research to organise the presentation of questionnaire items in a format that prevents respondents from identifying the scales to which items belong. The underpinning assumption, which derives from the psychometric research paradigm, is that respondents should answer each question 'on its merits' rather than engage in an interpretive exercise that might result in them developing an understanding of what the questions are 'really asking'. It has been assumed that if respondents understand the significance of an item, from the researcher's perspective, then their response might be biased by their attitude towards the purpose of the research. In other words, traditional approaches to research have sought to find ways of making the research agenda invisible to respondents. However, the results of our research on the new CLES caused us to challenge our assumption that by presenting items in a decontextualised way meaningful responses can be ensured.

We endeavoured to provide students with a more meaningful context for responding to the CLES items by making the following refinements to the new CLES , a copy of which is contained in the appendix.

1. We abandoned the traditional cyclic format of learning environment instruments in favour of presenting items grouped in their respective scales, and provided a 'user-friendly' title for each scale and for the whole questionnaire.

2. We produced a more economical 30-item version by reducing each of the five seven-item scales to a total of six items, by rejecting items whose wording was conceptually complex, and by minimising the use of negatively-worded items so that only a single negatively-worded item remains (i.e., Item 6).
Table 5 shows the scale membership of items in our refined version of the new CLES.

Table 5
Allocation of Items to Refined CLES Scales
(6 items /scale)

CLES Scale	Item Numbers					
Personal Relevance	1	2	3	4	5	6
Uncertainty	7	8	9	10	11	12
Critical Voice	13	14	15	16	17	18
Shared Control	19	20	21	22	23	24
Student Negotiation	25	26	27	28	29	30

NB Item 6 should be reverse-scored

Of course, further research is needed to determine the viability of these changes to the CLES, changes that might be regarded as somewhat radical when viewed from the perspective of the tradition of learning environment research. We have taken a step in that direction by conducting a large-scale survey of the refined 30-item CLES.

Large-Scale Survey

We were interested in determining the viability of the refined 30-item Student Perceived version of the CLES for use in large-scale survey research, especially research associated with systemic teacher professional development programs that utilise constructivism as a major referent. The potential usefulness of the CLES would be enhanced by evidence of its statistical robustness, particularly the soundness of the five scales. We seized the opportunity of including the CLES in the Australian component of the *Third International Mathematics and Science Study (TIMMS)* that was about to be conducted in Australian secondary schools. The TIMSS is the latest in a series of worldwide studies sponsored by the International Association for the Evaluation of Educational Achievement (IEA) which examines the systemic provision of educational opportunity and its relationship with educational attainment. The Australian component of the study is organised by the Australian Council for Educational Research (ACER).

In Western Australia, the ACER randomly selected a sample of the State's 13-year old student population in Grades 8 and 9 in both government and independent schools. During November 1994, selected schools which agreed to participate in the TIMSS were sent a package of pencil-

and-paper instruments designed to obtain measures of student background information, achievement and attitude. We included the CLES in the package and, subsequently, received completed CLES questionnaires from a total of 494 13-year old students in 41 Grade 8 and Grade 9 science classes from 13 schools.

The CLES data were entered into an electronic file for statistical analysis. Missing responses were assigned the mid-range value of 3, which corresponds to the frequency response category 'Sometimes'. The data were subjected to item analysis using the individual student as the unit of analysis.

Internal Consistency of 30-Item CLES Scales

Table 6 shows the mean scale scores and standard deviation values. These results are useful inasmuch as they provide the first set of normative data for comparing the results of future research studies in school science that make use of the 30-item CLES.

Of particular interest in this study are the Cronbach alpha reliability coefficients which provide a measure of the internal consistency of each of the five CLES scales. In learning environment research, alpha coefficient values in excess of 0.70 are regarded generally as indicating satisfactory degrees of internal consisteny (Fraser, 1986).

In the case of the 30-item CLES, four of the scales (i.e., *Personal Relevance, Critical Voice, Shared Control, Student Negotiation*) have alpha reliabilities that greatly exceed this value and can be regarded, therefore, as having highly satisfactory degrees of internal consistency for the sample of 494 13 year-old science students involved in this study, especially for relatively short scales containing only six items. Although the remaining scale (*Uncertainty*) has a relatively lower alpha value (r=0.72), it also has satisfactory internal consistency for this sample.

Table 6
Descriptive Statistics of 30-Item CLES (N=494)

CLES Scale	Mean Score	Standard Deviation	Alpha Reliability
Personal Relevance	20.6	4.8	0.82
Uncertainty	18.7	4.3	0.72
Critical Voice	18.7	6.2	0.88
Shared Control	10.9	5.1	0.91

Student Negotiation	19.9	5.5	0.89

Independence of Each 6-Item CLES Scale

In learning environment research, it is important that each scale of a multi-scale instrument is sufficently independent of the other scales for it to provide a measure of a unique construct. One way of determining statistically the independence of a set of scales is to calculate a scale *intercorrelation matrix* which provides a measure of the extent to which the scores of each scale are independent of those of the other scales.

Table 7 shows the intercorrelation matrix for the 30-item CLES scores obtained from the 494 13 year-old science students. The values range from a low of 0.17 (*Shared Control-Personal Relevance*) to a high of 0.38 (*Critical Voice-Student Negotiation*), and indicate, for this study, that each of the five CLES scales has a satisfactory degree of independence. It appears that the CLES scales assess distinct, but somewhat overlapping, aspects of classroom environments.

Table 7
Intercorrelation of Scale Scores for 30-Item CLES (N=494)

	Uncertainty	Critical Voice	Shared Control	Student Negotiation
Personal Relevance	0.33	0.28	0.17	0.35
Uncertainty		0.29	0.28	0.28
Critical Voice			0.30	0.38
Shared Control				0.27

Future Use

The analyses of the data from our survey of 494 13 year-old science students provide positive indications of the statistical robustness of the 30-item CLES. These results encourage us to recommend that the CLES be used in evaluations of systemic reform initiatives that utilise constructivism as a major referent for the transformation of school science classroom learning environments.

Conclusion

This study has provided substantial evidence that the Student Perceived version of the new Constructivist Learning Environment Survey can be used to monitor the development of constructivist learning environments.

Our collaborative classroom-based case study of a teacher's attempts to transform the social reality of her Grade 10 science class in accordance with a constructivist epistemology showed the value of the new CLES for highlighting the somewhat beguiling co-existence of multiple learning environments. Analysis of multiple sources of data led us to attribute this phenomenon to students' varying responses to the press for radical changes to their learning roles. We are confident that teacher-researchers conducting action research studies of their own teaching, particularly studies that involve a constructivist transformation of their classroom environments, will find the new CLES valuable for contributing to the compilation of fine-grained analyses that yield rich profiles of selected students. In this type of study, the CLES can be used as a heuristic device to enrich a teacher-researcher's understanding of the impact on students of her teaching innovations and, importantly, alert her to the possible counter-productive impact of her reform endeavours.

We must remind the reader that only four of the five scales of the CLES were examined in the Grade 10 science study. The conceptual viability of the *Uncertainty* scale, which focuses on the provisional status of scientific knowledge, remains to be tested empirically. As a result of this study, we produced a refined 30-item version of the CLES by departing somewhat radically with established learning environment conventions. We eliminated most negatively-worded items and grouped items in their respective scales.

The statistical viability of all five scales of the 30-item CLES was examined in our large-scale study of nearly 500 13 year-old science students. The results show that, for this randomly-selected sample, the six-item CLES scales have highly satisfactory degrees of internal consistency and independence. Therefore, we are confident in recommending the CLES for use in monitoring systemic constructivist-oriented reforms in science education.

References

Belenky, M.F., Clinchy, B.M., Goldberger, N.R., & Tarule, J.M. (1986). *Women's ways of knowing.* New York: Basic Books.

Connelly, M. & Clandinin, J. (1988). *Teachers as curriculum planners: Narratives of experience*. New York: Teachers College Press.

Dawson, V. (1994). *An emancipatory approach to the teaching of ethics*. Unpublished MSc thesis. Perth, Australia: Curtin University of Technology.

Denzin, N. K. (1988). Triangulation. In J. P. Keeves (Ed.), *Educational research, methodology, and measurement: An international handbook* (pp. 511-513). Oxford: Pergamon Press.

Erickson, F. (1986). Qualitative methods in research on teaching. In M. C. Wittrock (Ed.), *Handbook of research on teaching* (3rd ed., pp. 119-159). New York: Macmillan.

Fraser, B.J. (1981). *Test of science-related attitudes (TOSRA).* Melbourne: Australian Council for Educational Research.

Fraser, B.J. (1986). *Classroom environment*. London: Croom Helm.
Fraser, B.J. (1994). Research on classroom and school learning climate. In D. Gabel (Ed.), *Handbook of Research on Science Teaching and Learning* (pp. 493-541). New York: Macmillan.
Fraser, B.J. & Walberg, H.J. (Eds.) (1991). *Educational environments and effects: Evaluation, antecedents and consequences*. Oxford: Pergamon Press.
Grundy, S. (1987). *Curriculum: Product or praxis?* London: The Falmer Press.
Habermas, J. (1978). *Legitimation crisis*. T. McCarthy (trans.). Boston: Beacon Press.
Kemmis, S & McTaggart, R. (1988). *The action research planner (3rd ed)*. Geelong: Deakin University Press.
Kyle, D. W. & McCutcheon, G. (1984). Collaborative research: Development and issues. *Journal of Curriculum Studies, 16*(2), 173-179.
McCarthy. T. (1985). *The critical theory of Jurgen Habermas (3rd printing)*. Cambridge, MA: Massachusetts Institute of Technology Press.
McNiff, J. (1993). *Teaching as learning: An action research approach*. London: Routledge.
Pusey, M. (1987). *Jurgen Habermas.* London: Ellis Horwood & Tavistock
Saphier, J. (1982). The knowledge base on teaching: It's here, now! In T. M. Amabile & M. L. Stubbs. (Eds.), *Psychological research in the classroom* (pp. 76-95). Brandeis University: Pergamon Press.
Schon, D. A. (1983). *The reflective practitioner: How professionals think in action*. USA: Basic Books.
Shymansky, J. A. & Kyle, W. C. (1991). *Establishing a research agenda: The critical issues of science curriculum reform*. Manhattan, KS: The National Association for Research in Science Teaching, Kansas State University.
Taylor, P.C. (1992). *An interpretive study of the role of teacher beliefs in the implementation of constructivist theory in a secondary mathematics classroom.* Unpublished doctoral thesis. Curtin University, Perth, Australia.
Taylor, P.C. (1993). The influence of researcher beliefs on constructivist teaching practice. In K. Tobin (Ed.), *The practice of constructivism in science and mathematics education* (pp. 267-297). Washington, DC: American Association for the Advancement of Science.
Taylor, P.C. (1993, Nov). *Teacher education and interpretive research: Overcoming the myths that blind us*. Paper presented at the 1993 International Conference on Interpretive Research in Science Education, National Taiwan Normal University, Taipei, Republic of China, November.
Taylor, P.C. (1994a). *Mythmaking and mythbreaking in the mathematics classroom*. Science and Mathematics Education Centre, Curtin University, Perth, Australia.
Taylor, P.C. (1994b, Dec). *Collaborative classroom-based action research: Persuasion or coercion?* Paper presented at the symposium on Contemporary Approaches to Research in Mathematics, Science and Environmental Education, Deakin University, Burwood, Victoria.
Taylor, P.C. & Fraser, B.J. (1991, April). *Development of an instrument for assessing constructivist learning environments*. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, L.A.
Taylor, P.C., Fraser, B.J. & White, L.R. (1994, April). *The revised cles: A questionnaire for educators interested in the constructivist reform of school science and mathematics*. Paper presented at the annual meeting of the American Educational Research Association, Atlanta, GA.
Watt, D. H. & Watt, H. (1982). Design criteria for collaborative classroom research. In T. M. Amabile & M.L. Stubbs (Eds.), *Psychological research in the classroom* (pp. 134-143). Brandeis University: Pergamon Press.

White, L. (1994, March). *Mathematics/science teacher, teacher/researcher, constructivist: Multiple roles and multiple dilemmas.* Paper presented at the annual conference of the National Association for Research in Science Teaching, Anaheim, California.

http://www.letus.northwestern.edu/msta/surveys/source-documents/validity_cles2.html
10/12/07