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The Development and Validation of an Instrument to Monitor the Implementation of Social Constructivist Learning Environments in Grade 9 Science Classrooms in South Africa

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Abstract This article describes the development and validation of an instrument that can be used to assess students' perceptions of their learning environment as a means of monitoring and guiding changes toward social constructivist learning environments. The study used a mixed-method approach with priority given to the quantitative data collection. During the quantitative data collection phase, a new instrument—the *Social Constructivist Learning Environment Survey* (SCLES)—was developed and used to collect data from 1,955 grade 9 science students from 52 classes in 50 schools in the Western Cape province, South Africa. The data were analysed to evaluate the reliability and validity of the new instrument, which assessed six dimensions of the classroom learning environment, namely, *Working with Ideas*, *Personal Relevance*, *Collaboration*, *Critical Voice*, *Uncertainty in Science* and *Respect for Difference*. Two dimensions were developed specifically for the present study in order to contextualise the questionnaire to the requirements of the new South African curriculum (namely, *Metacognition* and *Respect for Difference*). In the qualitative data collection phase, two case studies were used to investigate whether profiles of class mean scores on the new instrument could provide an accurate and "trustworthy" description of the learning environment of individual science classes. The study makes significant contributions to the field of learning environments in that it is one of the first major studies of its kind in South Africa with a focus on social constructivism and because the instrument developed captures important aspects of the learning environment associated with social constructivism.

Keywords Learning environment · Social constructivism · Mixed-method research · Secondary school

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Introduction

Constructivism as a learning theory has been widely accepted throughout the science education research community as a productive alternative to a behaviourist view of learning (Noddings 1990; Lebow 1993). The notion that a student can actively construct knowledge for conceptual understanding by drawing on their everyday experiences is supported by research (Duit et al. 2008). Both personal and social forms of constructivism (e.g. Confrey 1990; Brooks and Brooks 1999) are supported, but most curriculum reforms, as in the case of South Africa, place emphasis on social constructivism.

In 1994, South Africa saw a significant breakthrough toward a non-racial and democratic society. This breakthrough was accompanied by social changes to ensure that the country could cater for its people irrespective of race. Such a challenge necessitated curriculum reforms, which resulted in the introduction of three different curricula over the last 15 years, namely, *Curriculum 2005* in 1998 (Department of Education (DoE) 1997), the *Revised National Curriculum Statement* (RNCS) in 2002 (DoE 2002), and the *Curriculum Assessment and Policy Statement* (CAPS) in 2012 (Department of Basic Education (DBE) 2011). In the natural sciences, the RNCS places a strong emphasis on social constructivist-based theories of learning in science classrooms (DOE 2002), with CAPS advocating "an active and critical approach to learning rather than a rote and uncritical learning of given truths" (DBE 2011, p. 9). From theoretical considerations of social constructivism, here, teachers are expected to facilitate students' learning through numerous teaching strategies, including collaboration (e.g. Roth 2002), hands-on activities (e.g. Lebow 1993), making knowledge personally relevant to students (e.g. Stears and Malcolm 2005), performing investigations (e.g. Dunlap 1999), requiring students to express their critical opinion (e.g. Savery and Duffy 2001), and to guiding students to think beyond their current processes (e.g. Mayer 1998) within a social setting. Such strategies are indeed those advocated by the curriculum (e.g. DBE 2011), and teachers have thus been required to transform their classrooms toward social constructivist learning environments for some time.

The present study was carried out in the Western Cape—one of the wealthiest of the nine provinces in South Africa. Despite this comparative wealth, schools in this province vary in quality, particularly with regard to the availability of resources (e.g. Fiske and Ladd 2004; Phurutse 2005), teacher quality (e.g. Arnott et al. 1997; for a more general discussion of science teacher quality, see Parker (2010)), and student quality (e.g. Reeves 1999). Schools range from those that are well-resourced, to those that are under-resourced (i.e. no running water or electricity, an acute shortage of classrooms, etc.); some teachers are highly qualified, while others are often poorly qualified (particularly in science and mathematics and, as a result, many struggle with subject matter); and some students have well-developed foundational knowledge in school science, while others' is under-developed. Given the comparatively wealthy, but nevertheless, diverse school context of the Western Province in keeping with the rest of the country, locating the current study in this province is anticipated to provide a useful 'best-case scenario' for the general, national situation in terms of teachers transforming their classrooms toward social constructivist learning environments.

The present study aimed to develop and validate an instrument that could be used to monitor the transformation of classrooms towards the new social constructivist education goals of South Africa. To assist teachers, teacher educators and researchers to monitor and guide changes towards social constructivist classroom learning environments, we developed and validated an instrument that can be used to assess students' perceptions of their social constructivist learning environments.

Background

The field of learning environment research (LER) has grown over the past 30 odd years and numerous reviews (e.g., Fraser 1994, 1998a, 2007) highlight the development of varying lines of research and research methods. Commonly, many investigations use survey instruments to assess student perceptions, which provide a snapshot (Fraser 1998a) of the learning environment studied.

Instrument development in LER has a rich history, initially proceeding in Western countries like the USA, the Netherlands, and Australia, and then expanding to other parts of the world (e.g. Asia and Africa). Historically important questionnaires include the *Classroom Environment Scale* (Moos 1979) and the *Learning Environment Inventory* (Walberg 1979) used to assess the environment in high school settings. These instruments were followed by the development of other important questionnaires including the *My Class Inventory* (Fisher and Fraser 1981), a simplified version of the *Learning Environment Inventory* for students at the primary school level, and the *Questionnaire on Teacher Interaction* (Wubbels and Levy 1991) for assessment of students' perceptions of their teacher's interpersonal behaviour. More recently, questionnaires have been developed to assess specific learning environments, such as the *Constructivist Learning Environment Survey* (Taylor et al. 1997) for measuring the extent to which constructivist approaches are being adopted.

In South Africa, studies have used the *Science Laboratory Environment Inventory* (SLEI) (Adams 1996, 1997) and the *Constructivist Learning Environment Survey* (CLES) (Aldridge, et al. 2004), and new instruments such as the *Outcomes-Based Learning Environment Questionnaire* (OBLEQ) (Aldridge et al. 2006) and *Outcomes-Based Learning Environment Questionnaire—Western Cape* (OBLEQ-WC) (Critien 2009) have been developed.

This study drew on three instruments, namely, the *Constructivist Learning Environment Survey* (CLES), the *Individual Classroom Environment Survey* (ICEQ) (Fraser 1980, 1990) and the *Cultural Learning Environment Questionnaire* (CLEQ) (Fisher and Waldrip 1997) in the development of a new instrument. The CLES was the first instrument to be framed in constructivist rather than behaviourist terms. Much of the strength of CLES lies in its rigorous development and its validation in many studies (e.g. Aldridge et al. 2000; Kim et al. 1999; Dryden and Fraser 1998; Puacharearn and Fisher 2004). A shortened version of CLES was used by Johnson and McClure (2004), while in South African mathematics classrooms, the instrument was found to be valid and reliable (Aldridge et al. 2004). Moreover, the CLES has been modified for online use (Taylor and Maor 2000) through the *Constructivist On-Line Learning Environment Survey* (COLLES), showing its versatility and adaptability. As described elsewhere, relevant individual scales from ICEQ and CLEQ were also used in Taylor and Maor's study.

Traditionally, many LER studies investigated the differences between the actual and preferred learning environment, giving invaluable insight into students' perceptions of the actual and preferred learning environments (Fraser 1998b). In these studies, the "actual" form measured students' and teachers' perceptions of the actual classroom environment; while the "preferred" form measured students' or teachers' perceptions of the learning environment that they would ideally like. One of the most invaluable insights that these studies show (e.g., Fisher and Fraser 1983; Fraser and McRobbie 1995; Wubbels et al. 1991) is that students and teachers are more likely to prefer a more positive environment than the one actually present in the classroom. The present study used a preferred form of a questionnaire to allow teachers and researchers to examine students' perceptions of their ideal learning environment, as well as an actual form.

In summary, the present study drew on valid, economical and widely applicable assessment instruments available in the field of LER to investigate the social constructivist learning environments in Western Cape Province science classrooms. Moreover, the study extended past research by developing two new scales, and validating the new instrument for use in South Africa.

Research Methods

The data collected for the present study drew on various sources (as recommended by Erikson 1998), including survey data, observations of science classrooms and interviews with the students. The data were collected sequentially (Creswell 2003), beginning with the collection of quantitative and followed by the qualitative data. Quantitative data were collected in the form of a new survey instrument to establish to what extent important elements of a social constructivist learning environment were incorporated into lessons. Qualitative data were collected in the form of interviews, classroom observations and narratives, to establish whether the survey-based class profiles could provide an accurate and "trustworthy" (Creswell 2003) description of the learning environment of individual classes.

Sample

The data for the study were collected in two phases: a large-scale quantitative and then a small-scale qualitative data collection phase. The sample for the quantitative data collection included 1,955 grade 9 natural science students from 52 classes in 50 schools. These schools were representative of urban and public schools in the Western Cape Province, South Africa. The 50 schools were selected through stratified proportionate random sampling; "School fees constitute an important resource for schools and represent potential for creating an enabling teaching and learning environment" (Phurutse 2005, p.13). Moreover, school performance in South Africa is strongly linked to socio-economic differentials (Fiske and Ladd 2004; Van der Berg 2007; Van der Berg and Burger 2003) which, in turn, can be argued to be indicated by the amount of school fees parents pay. The schools were thus stratified, first, by district and then by level of resourcing in proportion to their allocation across the districts in the province. Three levels of resourcing were determined on the basis of a box-and-whisker plot analysis of the 2009 annual fees schools in the province levied. High (H), moderate (M) and low (L) levels were represented by annual school fees of R2251 and above, fees between R2250 and R301, and fees below R301, respectively.

The cases for the qualitative data collection included a science class at two different schools, whose selection was based on the profiles of classroom environment means generated through the large-scale quantitative data collection and the schools' level of resourcing. One class each was situated in a school with a high and low level of resourcing, respectively.

Development of the Classroom Environment Instrument

The primary purpose of the present study was to develop and validate a widely applicable and distinctive questionnaire for assessing learners' perceptions of their actual and preferred classroom learning environment in a social constructivist context. The development and validation of the questionnaire involved a number of steps, namely:

1. Conducting a review of the Department of Education policy documents, and national and international literature on constructivism to identify dimensions central to the educational philosophy of constructivist teaching.

2. Scales were selected to ensure that the dimensions are consistent with Moos' (1979) scheme for classifying the dimensions of any human environment: Relationship Dimensions (which measure the degree of people's involvement in the environment and the assistance given to each other); Personal Development dimensions (which measure the kind and strength of the personal relationships in the environment); and System Maintenance and System Change dimensions (which measure the degree of orderliness, control and responsiveness to change in the environment) (Aldridge et al. 2006).
3. Developing two new scales, pertinent to the South African situation, as well as adopting and adapting scales and items from widely used questionnaires such as the *Constructivist Learning Environment Survey* (Aldridge and Fraser 2000; Kim et al. 1999; Nix et al. 2005; Taylor et al. 1997), the *Individualised Classroom Environment Questionnaire* (Fraser 1980, 1990) and the *Cultural Learning Environment Questionnaire* (Fisher and Waldrip 1997).
4. Developing a parallel actual and preferred form of the questionnaire, to enable the collection of both the actual and preferred views.
5. As English is the second or third language of most learners in the Western Cape Province, translation of the items and instructions into Afrikaans and isiXhosa—the local vernacular languages—using back-translation as recommended by Brislin (1970).
6. Finally, field testing the instrument with one grade 9 natural science class in each of four schools, and subsequently interviewing a sub-sample of learners about the clarity and readability of the items and the item-response format.

The new instrument, called the *Social Constructivist Learning Environment Survey* (SCLES), consists of seven scales and between 4–10 items per scale. The SCLES includes scales from existing instruments that are considered relevant to social constructivist education, as well as two newly developed scales entitled *Metacognition* and *Respect for Difference*. The SCLES assesses:

- Investigation (the extent to which emphasis is placed on the skills and processes of inquiry and their use in problem-solving and investigation);
- Metacognition (the extent to which learners are aware of how they think about their science ideas);
- Respect for Difference (the extent to which students are able to listen to and respect the views of others that are different from their own);
- Personal Relevance (the extent to which learning is relevant to students' lives);
- Collaboration (the extent to which students perceive that they collaborate with others rather than act as individuals);
- Critical Voice (the extent to which students perceive legitimacy of expressing a critical opinion); and
- Uncertainty in Science (the extent to which students perceive the status of scientific knowledge to be provisional).

Table 1 provides a description of each SCLES scale and its relevance to social constructivist education according to recent South African curriculum documents. The items in the SCLES are listed in the Appendix.

In developing the questionnaire, all three languages, namely the English, Afrikaans and isiXhosa versions were included on the same questionnaire. Although English is the medium of instruction in the Western Cape Province, it is in fact the second or third language—after

Table 1 Description and origin of each SCLES scale and its relevance to social constructivism in South Africa

Scale and its origin	Description	Sample item	Moos' (1974) category
	The extent to which…	*In my natural science class…*	
Investigation (ICEQ)	Emphasis is placed on the skills and processes of inquiry and their use in problem-solving and investigation	I find out answers to questions by doing investigations	System
Metacognition (newly developed)	Learners are aware of how they think about their science ideas, i.e., by recognising, evaluating and reconsidering their ideas	When I discuss my ideas about science to my classmates, I explain my reasoning	Personal
Respect for difference (newly developed)	Learners are able to listen to and respect the views of others that are different from their own	I listen to my classmates' opinions about science	System and relationship
Personal relevance (CLES)	Learning is relevant to students' lives	I learn about the world outside of school	Personal
Collaboration (CLEQ)	Students perceive they collaborate with others rather than act as individuals	I like working in groups	Relationship
Critical voice (CLES)	Legitimacy of expressing a critical opinion	It's OK for me to question the way I am being taught	Personal
Uncertainty in science (CLES)	The status of scientific knowledge is provisional	I learn that science cannot provide perfect answers to problems	System/ personal

ICEQ Individualised Classroom Environment Questionnaire; *CLES* Constructivist Learning Environment Survey; *CLEQ* Cultural Learning Environment Questionnaire

their home language—for the majority of students. In line with its policy of additive multilingualism (see, for example, Plüddermann 1997), the South African Department of Education requires all students to learn in their home language and demonstrate competence in this language with respect to listening, speaking, reading, viewing and writing as part of the outcomes for the languages up to grade 9 (Department of Education 2002). In general, the grade 9 Afrikaans and isiXhosa students are able to read and write this language. To assist students to complete SCLES accurately, it was therefore considered desirable to provide students with English, as well as the Afrikaans and isiXhosa equivalents for each item.

The SCLES was translated into Afrikaans and isiXhosa. The translation process involved four main steps. Firstly, the English version was produced by drawing on various scales from past questionnaires and then developing two new scales described above. Secondly, two highly experienced language specialists in Afrikaans and isiXhosa, each translated the questionnaires into Afrikaans and isiXhosa, respectively. Thirdly, another set of independent Afrikaans and isiXhosa translators conducted an independent back-translation as recommended by Brislin (1970) of Afrikaans and isiXhosa versions into English. The back-translations were verified by three independent translators who checked the translations against the original English versions. Any further queries or comments generated were conveyed to the original translators, who refined their translations in order to capture the original English version meaning of the questionnaire. Beneath each English item in the SCLES, the Afrikaans and isiXhosa translations were given in different fonts, an arrangement also provided for the instructions and the response scales (Table 2)—for example:

I enjoy lessons in Natural Science
Ek geniet Natuurwetenskaplesse
Ndiyazonwabela izifundo zezeNzululwazi

To give the students confidence and to encourage them to complete the questionnaire, scales pertaining to issues with which the students were likely to be more familiar (e.g. *Investigation*) were sequenced earlier in the questionnaire than less familiar—and thus potentially more difficult—scales such as *Uncertainty in Science*. The response format consisted of a 5-point frequency scale of *Always*, *Often*, *Sometimes*, *Seldom* and *Never* (Table 2).

The actual and preferred response scales of the SCLES items were placed side-by-side on a single form of the questionnaire to provide a more economical format. Using this format, students are required to record what they perceive as actually happening in their class in the "actual" column and to record what they would prefer to happen in the "preferred" column (Table 2).

Case Studies

The present research also involved a qualitative case study approach (Creswell 2003). The qualitative component was guided by Lincoln and Guba's (1985) validity checks using three criteria, namely, prolonged engagement, persistent observation and member checks. Firstly, the criterion *prolonged engagement* allowed the researcher to gain a better understanding of the context when enough time was spent with the participants to build rapport and trust with them. Secondly, the criterion *persistent observation* allowed the researcher to identify crucial characteristics of the case by ensuring that the number and duration of observations was sufficient. Lastly, the criterion *member checks* allowed the researcher to verify emerging results and hypotheses by sharing key results with participants for the sake of enhancing credibility.

Selection of the schools to be observed and interviewed involved scrutiny of the 52 classroom profiles generated during the quantitative data collection. Of the five schools chosen for the qualitative data collection – selected on the basis of two criteria, namely, (1) the absolute high/low score for the actual perceptions, and (2) discrepancies between students' actual and preferred perceptions of their classroom learning environment for selected scales – two schools will be reported in the present study based on the differences in their level of resourcing. For each teacher in a school, a minimum of five consecutive lessons were observed, over a period of 5 weeks. The researcher used a non-participant observation method, where the researcher remained apart from the people observed (Borg and Gall 1989), in order to ensure minimal classroom interference with the normal classroom practice.

Focus group interviews were conducted with six randomly selected students from each class (three boys and three girls in each class). Student interviews were used to clarify why students responded to items the way they did, and to verify the classroom observations. During discussions with the teachers, the researcher applied an unstructured interview approach because the events and instances observed during the lessons differed from classroom to classroom. The discussions with each of the teachers, both formal and informal, were often based on their successes or failures when implementing strategies related to SCLES in their teaching. The student interviews were tape-recorded and transcribed for later analysis, as recommended by Kvale (1996) Interestingly, the students agreed to be tape-recorded during interviews, but the teachers did not, thus the researcher recorded the teachers' responses using detailed notes.

Table 2 An extract from the SCLES, illustrating the inclusion of the English, Afrikaans and isiXhosa versions of each item and the answer format

	Actual (How it is) *Werklikheid* (*Hoë dit is*) Eyenzekayo (Indlela eyiyo)					Preferred (How I want it) *Verkiesde* (*Hoe ek dit wil hê*) Enqwenelekayo (Indlela endinqwenela ibeyiyo)				
Collaboration *Samewerking* Intsebenziswano	Never *Nooit* Zange	Seldom *Selde* Inqabile	Sometimes *Soms* Ngam-axesha	Often *Gereeld* Soloko	Always *Altyd* Rhoqo	Never *Nooit* Zange	Seldom *Selde* Inqabile	Sometimes *Soms* Ngam-axesha	Often *Gereeld* Soloko	Always *Altyd* Rhoqo
I like working in groups. *Hou ek daarvan om in groepe te werk.* Ndiyathanda ukusebenza ngokwamaqela.	1	2	3	4	5	1	2	3	4	5
I like to work with other students. *Hou ek daarvan om met ander leerders te werk.* Ndiyathanda ukusebenza nabanye abafundi	1	2	3	4	5	1	2	3	4	5

Findings

Validity and Reliability of SCLES

A major objective of the present study was to develop and validate a questionnaire for monitoring the social constructivist learning environments in the Western Cape Province, South Africa. The data collected from 1,955 students in 50 schools were used to examine the reliability and validity of SCLES. As a first step, to ensure that the factors in a set of learning environment scales are expected to be correlated, a principal component factor analysis followed by a varimax rotation (Field 2009) was performed. The results are shown in Table 3.

Items from various scales with a factor loading of less than 0.3 were omitted from further analyses, that is, for the *Respect for Difference* scale (item 15), the *Investigation*/*Metacognition* scale (items 24, 26, 27, 28 and 29), the *Personal Relevance* scale (items 34 and 35), the *Critical Voice* scale (items 43 and 44), and the *Uncertainty in Science* scale (item 48) (Table 3). The revised instrument shown in the Appendix therefore consisted of 34 items. In addition, the *Investigation* and *Metacognition* scales came together during the factor analysis, suggesting that students regarded *Investigation* and *Metacognition* in similar ways. This scale was subsequently re-named *Working with Ideas*.

Table 3 also presents the percentage variance and eigenvalues for each scale. For the actual form, the percentage of variance accounted for by the different scales ranged between 3.7 and 17.5 %, with the total variance accounted for being 44.7 %. The eigenvalues ranged between 1.2 and 5.9 for the scales (Table 3). Overall, the pattern of factor loadings, for the actual version in Table 3, provides good support for the *a priori* structure of the SCLES (albeit that the *Investigation* and *Metacognition* scales came together to form one scale).

For the revised 34-item SCLES instrument (Appendix), three further indices of scale reliability and validity were generated for the actual and preferred versions of the instrument (Table 4). Cronbach's alpha reliability co-efficient was used as an index of scale internal consistency of the actual and preferred versions. A discriminant validity index (i.e. the mean correlation of a scale with the other five scales) was used as evidence that each scale in the actual and preferred versions of the SCLES measures a separate dimension that is distinct from the other scales within the questionnaire. Analysis of variance (ANOVA) results were used as evidence of the ability of the actual form of each scale to differentiate between the perceptions of students in different classrooms.

Table 4 shows that the internal reliability (Cronbach's alpha co-efficient) for the actual version of the SCLES scales ranged between 0.62 and 0.82 with the individual as the unit of analysis, and between 0.58 and 0.94 using the class mean as the unit of analysis. For the preferred version of SCLES, the internal consistency reliability of scales ranged between 0.59 and 0.85 for the individual as the unit of analysis, and between 0.59 and 0.92 using the class mean as the unit of analysis. Overall, these results indicate that the internal consistency for both the actual and preferred versions of the SCLES is satisfactory.

For the actual version of SCLES, the discriminant validity (mean correlation of a scale with other scales) ranged between 0.23 and 0.31 with the individual as the unit of analysis, and between 0.06 and 0.37 with the class mean as the unit of analysis (Table 4). For the preferred version of SCLES, the discriminant validity ranged between 0.32 and 0.39 with the individual as the unit of analysis, and between 0.26 and 0.49 for the class mean as the unit of analysis (Table 4). These results suggest that the scales in the actual version of SCLES assess distinct constructs, although there is a degree of overlap. However, the factor analysis (Table 3) attests to the independence of factor scores on the actual form of the SCLES. The results for the

Table 3 Factor loadings for a modified version the 'actual' form of SCLES in South Africa

Factor loading						
Item no.	Working with ideas	Respect for difference	Personal relevance	Collaboration	Critical voice	Uncertainty in science
9	0.68					
10	0.51					
11	0.63					
12	0.53					
13	0.70					
14	0.58					
21	0.54					
22	0.65					
23	0.60					
25	0.60					
16		0.46				
17		0.63				
18		0.57				
19		0.63				
20		0.62				
30			0.67			
31			0.56			
32			0.77			
33			0.73			
36				0.79		
37				0.72		
38				0.66		
39				0.41		
40				0.70		
41					0.66	
42					0.71	
45					0.51	
46					0.58	
47					0.63	
49						0.60
50						0.63
51						0.56
52						0.65
53						0.63
Variance (%)	17.48	4.99	3.72	8.16	4.25	6.13
Eigenvalue	5.94	1.70	1.27	2.78	1.45	2.09

Factor loadings smaller than 0.30 have been omitted. The sample consisted of 1,955 students in 52 classes in South Africa

preferred version of the SCLES suggest that the raw scores assess somewhat overlapping aspects of the learning environment.

An analysis of variance (ANOVA) with class membership as the independent variable was used to determine whether the actual form for each SCLES scale was able to distinguish between the perceptions of students in different classes. The eta^2 statistic for each scale (Table 4) indicates that each SCLES scale differentiated in a statistically significant manner ($p < 0.001$) between classes.

Taken together, the results from the factor analysis, as well as the indices of scale reliability and validity (Cronbach's alpha reliability index, the discriminant validity index and ANOVA), suggest that the *Social Constructivist Learning Environment Survey* is reliable and valid for use in high school natural science classes in South Africa and therefore can be used with confidence by teachers and researchers in the future.

Using SCLES to Describe Typical Classrooms in the Western Cape Province

Using descriptive statistics, the learning environment of natural science classes was analysed based on students' responses to the SCLES. The scales of SCLES were used to describe a typical natural science classroom environment in the Western Cape Province. Because the number of items in each scale ranges between 4 and 10, the average item mean (i.e. the scale mean divided by the number of items in the scale) was calculated and used as the basis for describing the different classrooms. Table 4 reports the results in terms of the average item means for the class as unit of analysis for both the actual and preferred scores for the scales *Working with Ideas*, *Respect for Difference*, *Personal Relevance*, *Collaboration*, *Critical Voice* and *Uncertainty in Science*.

Table 4 Internal consistency reliability (Cronbach's alpha co-efficient), discriminant validity (mean correlation with other scales) and ability to differentiate between classrooms (ANOVA results) for two units of analysis for the modified version of the SCLES

Scale	Unit of analysis	No. of items	Alpha reliability		Mean correlation with other scales		ANOVA eta^2
			Actual	Preferred	Actual	Preferred	Actual
Working with ideas	Individual	10	0.82	0.85	0.24	0.38	0.19***
	Class mean		0.94	0.92	0.28	0.26	
Respect for difference	Individual	5	0.62	0.70	0.27	0.39	0.09***
	Class mean		0.77	0.91	0.37	0.33	
Personal relevance	Individual	5	0.67	0.69	0.23	0.34	0.11***
	Class mean		0.86	0.88	0.37	0.38	
Collaboration	Individual	5	0.72	0.76	0.24	0.32	0.06***
	Class mean		0.77	0.84	0.06	0.30	
Critical voice	Individual	5	0.66	0.59	0.28	0.32	0.06***
	Class mean		0.63	0.59	0.24	0.27	
Uncertainty in Science	Individual	5	0.69	0.71	0.31	0.39	0.05***
	Class mean		0.58	0.84	0.32	0.49	
Attitude	Individual	8	0.82				
	Class mean		0.96				

The sample consisted of 1,955 students in 52 classes in South Africa. The eta^2 statistic (which is the ratio of "between" to "total" sums of squares) represents the proportion of variance explained by class membership

***$p < 0.001$

The results in Table 5 show that the students' perceptions of the actual learning environment ranged between 3.15 and 3.82 for different scales. The average item mean for the learning environment that students would prefer ranged between 3.92 and 4.20 for different scales. A one-way ANOVA was performed with the six SCLES scales as the dependent variables and the form (actual or preferred) as the independent variable. The multivariate test yielded statistically significant results ($p < 0.001$) in terms of Wilks' lambda criterion, indicating that there were differences in the set of criteria as a whole. Therefore, the one-way ANOVA was interpreted for each of the six individual SCLES scales. The results of the *F* tests are shown in Table 5 along with descriptive statistics. In order to estimate the magnitudes of the differences (i.e. in addition to their statistical significance), effect sizes (i.e. magnitudes of the differences expressed in standard deviation units) were calculated as recommended by Thompson (1998, 2002).

The results reported in Table 5 indicate statistically significant differences ($p < 0.001$) between the actual and preferred scores for all six learning environment scales for the class mean as the unit of analysis. The effect size for each of the SCLES scales ranged between approximately 1.65 and 3 standard deviations for the class mean as the unit of analysis (Table 5). These results suggest that there are large differences between students' perceptions of their actual and preferred environment.

Using SCLES for describing the learning environment of individual classes

Individual profiles of the learning environment scores for each of the 52 classes surveyed were scrutinised. In many ways, the trends observed were similar. However, closer inspection of the profiles showed that for some classes, the discrepancies between students' perceptions of the actual learning environment and their preferred learning environment were unusually large or small. To investigate whether the profiles generated for the individual classes were a valid and "trustworthy" reflection of what was happening in the classroom, two classes were selected based on either good or poor correspondence between the actual and preferred scores on the dimensions, and these two classes, class A and class B, are discussed below.

Class A

This class is in a girls-only school in an affluent area in Cape Town, South Africa. Given the annual school fee of R11,980 per year, the school was categorised as having high socio-economic

Table 5 Average item mean, average item standard deviation for differences between the scores of the actual and preferred perceptions on the SCLES (effect size and ANOVA results) for the class mean as the unit of analysis

Scale	Average item mean		Average item standard deviation		Differences	
	Actual	Preferred	Actual	Preferred	Effect size	*F*
Working with ideas	3.15	3.95	0.32	0.21	3.01	226.09***
Respect for difference	3.82	4.20	0.21	0.25	1.65	67.81***
Personal relevance	3.38	3.92	0.28	0.29	1.89	97.37***
Collaboration	3.75	4.12	0.20	0.21	1.80	86.38***
Critical voice	3.62	4.00	0.20	0.19	1.95	101.32***
Uncertainty in science	3.50	3.95	0.17	0.21	2.37	144.51***

The sample consisted of 1,955 students in 52 classes in South Africa

***$p < 0.001$

status (SES). The school is well-resourced in terms of its infrastructure with regard to four important aspects. First, facilities such as water and electricity are available in all the classrooms. Second, the school is secured with a variety of measures, namely, a security guard who patrols during the day and night, fencing surrounding the perimeter of the school and intercoms at various gates. Third, there are five science classrooms and one large computer room, both with functional equipment. The science classrooms house laboratory desks and chairs, microscopes, a variety of chemicals and many science teaching aids. The computer room is equipped with 30 computers and is run by a computer science teacher. Each computer has internet access and software related to science learning. Finally, other important facilities include a school library with many science books for use during projects and research, as well as a staffroom for teachers.

This comparatively large school (853 learners) is staffed by well-qualified teachers, all of whom have university degrees. Fifty percent of the teachers are employed by the government (i.e. the provincial education department) and the rest by the school (i.e. School Governing Body (SGB)). The SGB was formed from the early 1990s when the White government schools were able to enrol Black students if the SGB gave permission. The SGB also monitors the school fees charged, so that additional funding can be used to employ extra teachers. At school A, sufficient teachers could be employed to limit the class size to a maximum of 35 students.

The teacher of class A is a female in her mid-20s. She has a Science degree and 4 years teaching experience. She confirmed that during her initial teacher training, she was exposed to the notion of social constructivism on numerous occasions and was therefore familiar with the concept. She claimed that she tried to incorporate the dimensions of social constructivism in her lessons. The teacher's teaching approach generally incorporated active involvement of all students, with the main thrust focusing on approaches like class discussions and debates. Focus group interviews with the students suggested that they enjoyed being actively involved in lessons. Furthermore, they were eager to be involved in lessons as the teacher encouraged them to participate in lessons because of her approachable, warm and non-threatening disposition. They said, for example, “Miss allows us to ask any questions. We never feel stupid when talking to her”. The students were also aware that the teacher encouraged debate by creating opposition in science lessons through her strong religious viewpoints. They said, “Sometimes Miss will say something about religion that goes against science evidence. Some students will agree while others might disagree”. One student added, “Sometimes when she challenges us with the religious views, it makes the lesson more interesting”. When interviewing the teacher, it was evident that her religious viewpoint featured frequently in her teaching of science. She stated, “My religious viewpoint makes me more objective about science; as a consequence, I often prepare lessons that polarise opinions, leading to class debate”. The teacher added, “My light workload gives me time to do research for lesson preparation. I tend to focus on class discussion and debate as I know this class enjoys it”.

The average item mean for students' actual and preferred scores for each SCLES scale for class A is given in Fig. 1. A striking feature of the learning environment profile of this class is the large disparity between the actual and preferred learning environment scores for the scales *Working with Ideas*, and to a lesser degree, for *Uncertainty in Science* and *Respect for Difference*. The large student-perceived disparity on the actual and preferred learning environments score on the scale *Working with Ideas* surprised the teacher. Through interviewing the teacher, it became apparent that, to a large degree, she struggled to cover the necessary content given the limited amount of time she taught the students per week. She taught the class only four lessons a week, and thus economised on her time by modifying her teaching through a two-part teaching approach. She said, “I take on a structured approach to teaching in order to economise on my class time with the students”. Indeed, further interviews revealed that in the

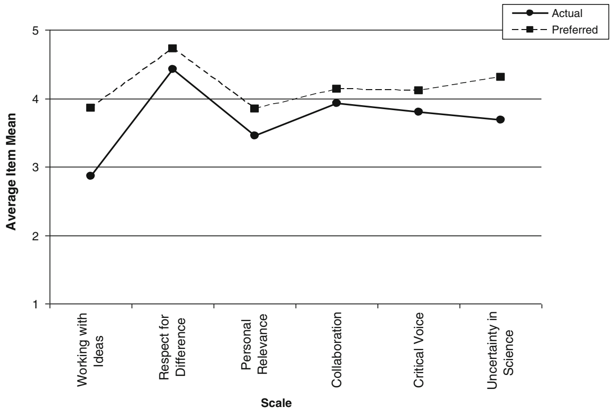

Fig. 1 Average item mean for students' scores on the actual/preferred learning environment scales of the SCLES for the case study of class A

first part of the approach, she spent at least two lessons guiding the students in the development of a concept. She claimed that in doing so, she incorporated methods to allow students to "think about their thinking", which she claimed was a form of "metacognition". In the second part, the students themselves developed the concept independently, particularly through independent or group-related research projects and investigations. This could very likely have made students perceive the two scales *Investigation* and *Metacognition* similarly, hence the combination of the two scales in the factor analysis, forming the new scale *Working with Ideas* (Table 3). The teacher of class A claimed that this approach allowed her to complete the content requirements of the topic:

> With the time restrictions imposed by the Department of Education, and the whole of the last term being devoted to tests and examinations, as well as marking them, I have to adopt teaching approaches that help save time during lessons—for instance, I do many investigations.

With regard to the scale *Uncertainty in Science*, there was a fairly large discrepancy between the actual and preferred learning environment scores (Fig. 1). The teacher said, "Students in this class are still experimenting with the concept of the uncertainty in science. There are many doubts, and I am trying to help them develop this idea". Evidence of the students' doubt about the possibility that science can be questioned was unearthed in the classroom interviews. Furthermore, the students believed that science should not be questioned. They stated, "All previous teachers in science have told us that we should not question them [the teacher] or the textbook. All the answers in the textbook are correct". Classroom observations revealed that the teacher helped the students by allowing them to explain their ideas to the class and encouraged theorising through thinking about all possibilities and options. She furthermore guided the students to help them make sense of the fact that science knowledge can, on occasions, be uncertain.

The high score and small discrepancy for the scale *Respect for Difference* (Fig. 1) was very likely due to the teachers' pivotal role in enforcing transparent rules based on respect for varying opinions. The interview with the teacher made it apparent that creating a clear set of rules, which were openly discussed with the students, and therefore transparent, made them want to respect each other's views. She said, "I encourage the girls to express their opinions by clear rules based on respect". The students' awareness of the rules set by the teacher played a crucial role in the students implementing them. Interviews with the students revealed that they were aware of the rules in their class:

> …we know that when other students speak, we must listen, and Miss [the teacher] insists on it. This allows us to feel free to express ourselves in our class, even to Miss. She makes us feel comfortable to express our ideas and opinions in this class.

Class B

This class is at a co-educational school situated in a poor, gang-infested area in Cape Town. Given the annual school fee of R210 per year, the school was categorised as low SES. The school is well-resourced in terms of its infrastructure with regard to water and electricity, which is available in all the classrooms. However, there are numerous problems regarding classroom infrastructure. For instance, although a charity organisation donated 30 computers, vandalism resulted in many computers in the five science classrooms and two computer rooms where they were housed to be damaged or stolen. The consequences of vandalism were also apparent in the science classrooms, evident by the broken laboratory desks and chairs, broken plug points and broken or stolen teaching aids. Consequently, security is an important issue for the infrastructure in this school. Nevertheless, the schools limited funds have resulted in its reliance on the school cleaner to double as a security guard during school hours.

Twenty-six teachers staff this comparatively large school (891 students). Most teachers have teaching diplomas from teacher training colleges. A small percentage have university degrees combined with postgraduate teaching diplomas. The teacher claimed during interviews that he had a big workload. He said, “I teach all five grade 9 classes. I prepare all the tests and worksheets, and mark them. As a result, I have marking throughout the year, even during school holidays!” The teacher also claimed that there is a large staff absenteeism rate. He said, “Many teachers are absent in the week; sometimes I have no free periods as I have to substitute in those classes”. The teacher therefore claims that he has little time to prepare lessons for the students.

The teacher of Class B is a male in his mid-40s. He is qualified with a teaching diploma obtained from a former teacher training college. He claims that he had limited exposure to social constructivist teaching approaches during his teacher training but recently attended some workshops hosted by the provincial Department of Education and came across the term. He said:

> Perhaps I don’t call it a fancy word like the Department of Education does, but I make every effort to allow the students to participate in discussions, collaborate and debate. However, given the nature of this class, they are passive and all interactions end up with them expecting me to give them the ‘right’ answers.

Classroom observations reveal that he is warm, friendly and approachable toward the students. During student interviews, students claimed, “Sir is nice to us and we always ask him questions”. The students added that the teacher also helped them when they had personal problems. One student said, “Sir helped me when I had no bus fare to go home”. Another added, “Sir gave me pens and pencils when my mother had no money”. An interview with the teacher regarding the students revealed that he found teaching this class challenging. He said, “Dealing with these students is emotionally draining as they come from impoverished backgrounds, and many come to school bearing the emotional consequences of these problems”. On many occasions, the teacher claimed that he had to stop his teaching to deal with students who felt faint because they were hungry or counsel a child who was emotionally troubled—many because of abuse at home. Sometimes, he says, the blank looks on their faces tell him that they do not understand what he is saying. He claimed that language issues clouded their learning as many students struggled to link their school language with colloquial language at home and on the street.

The average item mean for students' actual and preferred scores for each SCLES scale for Class B is shown graphically in Fig. 2. A striking feature of the learning environment profile of this class is the fairly small disparities between the actual and preferred learning environment scores for the dimensions *Working with Ideas* and *Personal Relevance*.

The fairly small discrepancy between the actual and preferred learning environment scores for the scale *Working with Ideas* was noteworthy as it represented the smallest discrepancy of all the 52 classrooms in the study. Interviews with the teacher made it evident that he approached teaching this class by focusing mainly on explaining concepts in class, and rarely focusing on independent investigations by the students. His rationale for this approach was twofold. Firstly, he explained concepts guided by textbook-bound exercises (mainly one textbook), as he felt that students themselves needed constant guidance in class in developing their understanding of concepts. He verified this when he said, "Textbook-bound exercises work best with this class. Students prefer to work in this way as they are able to get the right answers from me". Secondly, he rarely allowed students opportunities for independent investigation as, he claimed, the vast majority of students had limited exposure to libraries or the internet, and thus research material. Furthermore, if access was possible, then students would waste time, as many were computer illiterate (students were not formally taught computer lessons as it was not included in the school curriculum) and few knew how to access relevant research material at the library due to lack of training. As a result, the teacher claimed that doing exercises in class would waste less time and was evidently the best strategy for him.

Interviews with the students revealed that they were generally satisfied with the teacher's approach, though students interviewed during the focus group sessions suggested that they would prefer more independent work to develop understanding of concepts. The group generally agreed with the teacher's teaching approach by saying, "We like the way Sir teaches". However, two students who wanted more investigations said, "If we could do work on our own, the work would be more interesting, perhaps Sir can get material, like books or internet material for us, then we could do experiments at home to prove our ideas". On the whole, it seemed evident that the students were generally satisfied with the teachers' approach, hence, the fairly small discrepancy between the actual and preferred learning environment scores.

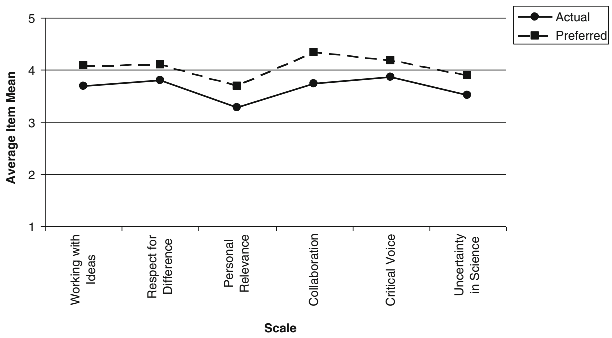

Fig. 2 Average item mean for students' scores on the actual/preferred learning environment scales of the SCLES for the case study of class B

The relatively low mean scores on the scale *Personal Relevance* was likely to be a result of the rather traditional teaching approach adopted by the teacher. In addition, classroom observations reveal that there were few opportunities for student involvement during lessons. Thus, students might have felt marginalised from participating, separating their school learning experiences from their personal life experiences. Indeed, interviews with the teacher revealed that this may be so, as he claimed, “It is difficult to interact with this class as they are so quiet”. It might be that students were marginalised at two levels, firstly, as mentioned above, by the teacher. Secondly, it could be that cultural differences between the teacher and students might have impeded his progress with them in lessons. Indeed, the teacher claimed during interviews that when he attempted to make classroom discussions and activities relevant to the students’ everyday lives, the students seldom responded. He speculated that cultural differences between him and the students might have resulted in him not relating to the students, and in not truly identifying with their everyday life situations. On the other hand, it might be that students were comfortable with an adult dominating their lessons in a manner consistent with their cultural understanding of the roles adults play, resulting in the smaller discrepancy between the actual and preferred learning environment scores.

Discussion and Conclusion

The development and validation of a questionnaire—the *Social Constructivist Learning Environment Survey* (SCLES)—to monitor the learning environment of natural science classrooms in the Western Cape Province in light of recent national curricular demands is timely. The questionnaire provides teachers and students with an accessible means of monitoring changes within natural science classes. It was rigorously designed, and captures important aspects of the learning environment associated with social constructivist teaching approaches.

This study involved the collection of data from 1,955 learners form 52 classes in 50 schools. The data were analysed to determine the validity and reliability of the SCLES in terms of its factor structure, internal consistency reliability, discriminant validity and ability to differentiate between classrooms. The factor structure for the actual form of the SCLES indicated that students respond to *Investigation* and *Metacognition* in similar ways. Therefore, these two scales were combined to form one scale—subsequently re-named *Working with Ideas*. For all six scales (*Working with Ideas*, *Respect for Difference*, *Collaboration*, *Personal Relevance*, *Critical Voice* and *Uncertainty in Science*), all items have a factor loading of at least 0.30 on their *a priori* scale and no other scale.

The internal consistency reliability estimate (Cronbach’s alpha co-efficient) for each of the six scales for both the actual and preferred forms of the SCLES, using both the individual and the class mean as the unit of analysis, was comparable with past studies (Aldridge and Fraser 2000; Aldridge et al. 1999; Kim et al. 1999). The results of one-way ANOVAs indicated that the “actual” form of each scale was able to differentiate between the environments of different classes. Similarly, the Cronbach’s alpha co-efficient for the *Attitude toward Science* scale was found to be satisfactory (i.e. 0.82 and 0.92 for the individual and class means, respectively). Past research studies also found the *Attitude toward Science* scale to be reliable (e.g. Henderson and Reid 2000; Kourous and Abrami 2003; Margianti et al. 2002; Rawnsley and Fisher 1998). Overall, the validation provides for the confident future use of the SCLES in high school grade 9 natural science classes in South Africa.

A one-way ANOVA and effect sizes were used to investigate differences in scale scores between students’ perceptions of the actual learning environment and their preferred learning environment. There was a significant difference for all six learning environment scales, with students preferring a more positive learning environment than the one that they presently perceive on all SCLES dimensions. The magnitude of the differences, calculated using effect sizes, ranged from approximately one and a half standard deviations (1.65) to over three standard deviations (3.01). These results suggest educationally important differences between students' perceptions of the actual and preferred learning environment. The discrepancies between the actual and preferred perceptions came about mostly as a result of teachers' classroom practices. This is not surprising as teachers play a pivotal role in shaping and creating learners' classroom perceptions. Research has shown that teachers' personal teaching approaches as well as their daily moods play an important role in terms of creating the classroom climate (Fraser 2007). Overall, the finding that students in the Western Cape province would generally prefer a more favourable learning environment than the one that they perceive replicates international findings in secondary schools (Fraser 1998b), as well as locally (Aldridge et al. 2006). The results from this study should have implications for both professional development programmes, both pre-service and in-service, and classroom practices in South Africa.

Case studies of two different classrooms, using classroom observations and interviews with students and teachers, confirmed that profiles of class mean scores on SCLES scales can provide accurate and "trustworthy" descriptions of the learning environment of individual classes. Moreover, the findings of this study suggest that the success or otherwise of implementing different components of social constructivist learning environments is very likely SES-influenced, contrary to the results of Aldridge et al. (2006) who claimed that the implementation of OBE might not necessarily be dependent on the "quality" of the teacher and school, but could be related to logistical and organisational factors (e.g. length of periods, large class sizes, availability of books, etc.), teachers' views of students' attitudes towards and conceptions of learning, and the perceived difficulty of the science content taught.

A critical evaluation of the perception of students' actual and preferred social constructivist classroom learning environments could show the degree of capability, as well as the level of success, of teachers in the Western Cape province in implementing social constructivist education in their classrooms. Could have implications for both professional development programmes for teachers and classroom practice in South Africa, especially pre-service and in-service teacher training programmes. The development of a new instrument to measure students' perceptions of their social constructivist learning environment provides an important new tool for teachers, teacher educators and researchers in South Africa and elsewhere.

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Appendix: Original English version of SCLES

Investigation/Metacognition

9. I am asked to think about the supporting facts for statements.
10. I carry out investigations to answer questions coming from discussions.
11. I explain the meaning of statements, diagrams and graphs.
12. I carry out investigations to answer the teacher's questions.

13. I find out answers to questions by doing investigations.
14. I solve problems by using information obtained from my own investigations.
21. I think about my ideas in science.
22. I write down my ideas in science.
23. I check my ideas in science with my teacher.
24. I check my ideas in science by reading.

Respect for difference

16. I am aware that my classmates have different opinions about science.
17. I listen to my classmates' opinions about science.
18. Before I agree or disagree with my classmates' opinions about science, I first think about what they said.
19. I try to understand my classmates' opinions about science.
20. I respect my classmates' opinions about science.

Personal Relevance

30. I learn about the world outside of school.
31. My new learning starts with problems about the world outside of school.
32. I get better understanding of the world outside of school.
33. I learn interesting things about the world outside of school.
36. What I learn I can link to what I already know.

Collaboration

37. I like working in groups.
38. I feel that it is important for the class to work together as a team.
39. I would rather decide what to do as a group than to make a decision by myself.
40. It is important for me to be involved in class discussions.
41. I like to work with other students.

Critical Voice

42. It's okay for me to ask the teacher "Why do I have to learn this?"
45. It's okay for me to complain about anything that prevents me from learning.
46. It's okay for me to express my opinion.
47. It's okay for me to speak up for my rights.

Uncertainty of Science

49. I learn that science has changed over time.
50. I learn that science is influenced by peoples' values and opinions.
51. I learn about the different sciences used by people in other cultures.

52. I learn that modern science is different from the science of long ago.
53. I learned that science is about creating theories.

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