

Using teacher action research to promote constructivist learning environments in South Africa

Jill M. Aldridge and Barry J. Fraser*

Science and Mathematics Centre, Curtin University of Technology, GPO Box U1987, Perth, 6845 Western Australia
J.Aldridge@curtin.edu.au; B.Fraser@curtin.edu.au

Mokgoko P. Sebela

Department of Education, Capricorn District, Limpopo Province, Private Bag X506, Groothoek Hospital, 0628 South Africa
mokgoks@iafrica.com

* To whom correspondence should be addressed

The primary focus was to assist South African teachers to become reflective practitioners in their daily mathematics classroom teaching. The study involved a combination of quantitative and qualitative research methods. Quantitative data were collected using the Constructivist Learning Environment Survey (CLES) to assess learners' perceptions of the emphasis on constructivism in the classroom environment. In the first phase of the study, the CLES was administered to 1 864 learners in 43 classes and analysed to determine whether the CLES is valid and reliable for use in South Africa. As well, descriptive analysis was used to generate graphical profiles of learners' perceptions of the actual and preferred learning environment for each class. During the second 12-week intervention phase, two teachers used the profiles to assist them to develop strategies aimed at improving the constructivist orientation of their classroom learning environments. The teachers implemented strategies and maintained a daily journal as a means of reflecting on their teaching practices. At the end of the 12 weeks, the CLES was re-administered to learners to determine whether their learners' perceptions of the constructivist emphasis in their classroom learning environments had changed.

Introduction

After the new South African government came into existence in 1994, the education Minister, Professor Bengu, embarked on changing the education system. It was decided that from 1998 the old curriculum, under which blacks, Indians, coloureds and white learners studied different curricula, would be phased out and gradually replaced by Curriculum 2005. Curriculum 2005 is based on the ideal of lifelong learning for all the South Africans, regardless of colour, race or sex. The curriculum focuses on fostering learning that encompasses a culture of human rights, multilingualism, multiculturalism and sensitivity to the values of reconciliation and nation building.

Teaching practices, adopted through Curriculum 2005, require that learners participate in classroom activities, become more involved in the learning process, and take responsibility for their own learning. It also requires that teachers give learners the opportunity to work at their own pace according to individual abilities and levels of development. Both teachers and learners are required to focus on predetermined results or outcomes that should be achieved during each learning process. It is envisaged that teachers, as facilitators in their own classrooms, will use a range of strategies, such as cooperative learning, experiential learning, inquiry or investigation, direct instruction, deductive and inductive learning, and problem solving.

The realities of teaching in South Africa pose numerous problems in terms of resources (Fullan, 1994) and adequately trained teachers (Edusource, 1997). In the light of the new curriculum, currently being put into practice in South Africa, it is important to examine ways to assist teachers to implement the necessary changes. One means by which teachers may be able to improve their classroom teaching practices could be through reflective practice. This research aimed to assist teachers in the development and implementation of improved classroom practices through reflection on their learners' perceptions of the learning environment (as assessed using the Constructivist Learning Environment Survey). This means that both the teacher's role and the classroom environment have to change as the curriculum changes.

Objectives

1. To modify and validate an actual and a preferred version of the Constructivist Learning Environment Survey (CLES) for use at the intermediate and senior levels of schooling in South Africa.
2. To describe the learning environment of typical classrooms in South African schools in terms of the dimensions assessed by the CLES.

3. To investigate whether teachers are able to make use of learner responses to the CLES to develop and implement action research strategies aimed at improving the learning environment.
4. To investigate the success of using journals as a means of encouraging teachers to reflect on teaching strategies and improve their learning environments.

Background and theoretical framework

Field of learning environments

Walberg and Moos initiated the field of learning environments research in the 1960s. Moos developed his first world-renowned social climate scales, which were used in hospitals and correctional institutions (Moos, 1981). At around the same time, Walberg developed the Learning Environment Inventory (LEI), which was used for the research and evaluation activities of the Harvard Project Physics (Walberg & Anderson, 1968). Since that time, researchers have developed numerous questionnaires to measure perceptions of a range of dimensions pertinent to the learning environment (Fraser, 1998). Fraser (1994; 1998) emphasises that the use of learners' perceptions of classroom environment as predictor variables has established consistent relationships between the nature of the classroom environment and the learner cognitive and affective outcomes. It is important, therefore, that teachers consider the learning environments that they create.

Constructivist learning environments and Curriculum 2005

Constructivist theory acknowledges that the teacher is not a transmitter of knowledge but rather a facilitator and provider of experiences from which learners will learn. Similarly, pupils are not absorbers of knowledge but active participants in constructing their own meaning based on strongly held preconceptions. According to constructivist theory, then, knowledge is a social construct (Taylor, Fraser & Fisher, 1997). Curriculum 2005 advocates the use of constructivist teaching methods to ensure a more learner-centred classroom (Department of Education, 1997). Our study examined how mathematics teachers in South Africa transform their classrooms, from ones that are more traditional and teacher-centred, towards ones that include teaching methods that reflect a more constructivist notion of teaching. To do this, the present study used the Constructivist Learning Environment Survey (CLES; Taylor *et al.*, 1997), which has the potential to address the improvement and development of social constructivist classroom learning environments in South Africa.

Using the CLES to monitor transformation in South Africa

The CLES was developed to provide feedback on teachers' attempts to transform their classroom learning environments in accordance with critical constructivist epistemology (Taylor *et al.*, 1997). The CLES was developed to enable teachers to monitor the transformation from a more teacher-centred approach to more constructivist teaching approaches and to address key restraints to the development of constructivist classroom climates in school science and mathematics (Taylor *et al.*, 1997).

The CLES assesses learners' perceptions of five dimensions pertinent to the notion of constructivism: *Personal Relevance* (the extent to which teachers relate science and mathematics to learners' out-of-school experiences); *Uncertainty* (the extent to which opportunities are provided for learners to experience mathematics and science knowledge as arising from theory-dependent inquiry, involving human experience and values, evolving and non-foundational, and culturally- and socially-determined); *Student Negotiation* (the extent to which opportunities exist for learners to explain and justify to other learners their newly developing ideas and to listen to and reflect on the viability of other learners' ideas); *Shared Control* (the extent to which learners are invited to share with the teacher control of the learning environment, including the articulation of their own learning goals, design and management of their learning activities, and determination and application of assessment criteria); *Critical Voice* (the extent to which there has been established a social climate in which learners 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).

The CLES is available in an actual and preferred form (Kim, Fisher & Fraser, 1999), the preferred form being concerned with goals and value orientations and assessing the learning environment that learners would ideally like. Past studies that have made use of the CLES have found that the instrument is robust and consistently displays high reliability and a consistent factor structure. The CLES has been validated in studies across several countries, including Korea (Kim *et al.*, 1999; Lee & Fraser, 2002), the United States (Dryden & Fraser, 1998; Johnson & McClure, 2002; Nix, Fraser & Ledbetter, 2003; Poth & Fraser, 2000; 2001), and Australia and Taiwan (Aldridge, Fraser, Taylor & Chen, 2000).

Action research

Action research provides teachers with an opportunity to apply the findings of traditional research to their own situations and to adapt theory to practice. It also involves teachers as participants in their own educational process, and helps them to develop a critical and reflective eye for their own instructional practices along with those of their peers (Lederman & Niess, 1997). Action research is participatory, involves people working towards the improvement of their practice, and is a powerful tool for change and improvement at the local level (Cohen, Manion & Morrison, 2000).

Through action research, teachers come to understand what is really happening in their classrooms. Action research increases teachers' feeling of self-worth and confidence and the awareness of classroom issues. Individuals and social groups are empowered to take control over their lives within a framework promoted through action research (Greenwood & Levin, 2000). Action research forces the teacher not to stand back and observe phenomena from a distance, but to take action and make things happen. In this study, action research was used to assist teachers to be active, collaborative, critical and self-critical in their teaching practices in mathematics in South Africa in the implementation of the new Curriculum 2005 (C2005).

Research methods

The present study had two phases. In the first phase, we examined whether the Constructivist Learning Environment Survey (CLES) could be modified and validated for use in South Africa. In the second phase, we investigated the usefulness of the CLES as a feedback tool

that teachers could use in action research to help them to implement more constructivist methods in their classrooms. This section provides information about how the research was conducted.

Large-scale data collection

The CLES was originally developed to assess the perceptions of high school science and mathematics learners, but the present study aimed to use it with intermediate and senior phase school mathematics learners. When the CLES was first used in countries outside Australia, such as Taiwan (Aldridge *et al.*, 2000), the United States of America (Dryden & Fraser, 1998), Nigeria (Idiris & Fraser, 1997) and Korea (Kim *et al.*, 1999; Lee & Fraser, 2002), it was found necessary to modify it to ensure its suitability for that country. It was important, therefore, that the CLES underwent a degree of modification to ensure its suitability for learners in South Africa.

Although the medium of instruction in South African schools is English, some terms and phrases within the CLES are unlikely to be understood by the average learner. To avoid confusion, the word 'learner' was substituted for 'student'. In addition, changes were made to make the CLES more suitable for use in 'mathematics' classes, as opposed to 'science' classes (for which it was originally designed to be used). Preceding each item, the phrase "In this mathematics class ..." was added.

The modified CLES was pilot-tested in three classes, with one located in a school selected from each of a rural, semi-rural (township area) and urban area. Six learners from each class were interviewed to check the readability of the items and to ensure that learners interpreted each item as intended.

The interviews with learners indicated that, when talking about the Critical Voice scale, learners were not happy to question the teacher about their learning. They felt that they did not have enough experience and that their parents were in a better position to interact with the teachers about such matters. In addition, these interviews indicated that, in many cases, statements were interpreted in ways that were not intended by the researchers, possibly because learners had not experienced the opportunity to voice criticism (as was the case when the CLES was used in Taiwan, see Aldridge *et al.*, 2000). Therefore, it was decided that the Critical Voice scale would be omitted. The final version of the CLES used in this study was composed of four subscales, with six items each assessing Personal Relevance, Uncertainty, Shared Control and Student Negotiation.

The modified CLES was administered to a sample of 1 864 intermediate (Grades 4 – 6) or senior level (Grades 7 – 9) learners in 43 classes. The sample involved 29 teachers in six schools selected from within the Capricorn region of the Limpopo province of South Africa. Every attempt was made to ensure that the sample selected was representative of the classes and schools in the area from which they were drawn.

Case studies

The second phase of the study focused on action research. From the 43 classes involved in data collection in the initial phase of the study, two teachers and one of their mathematics classes were selected as case studies. The selection of these teachers was based largely on their willingness to be involved in this phase of the study and on the proximity of the school to the researcher.

Using learners' responses to actual and preferred versions of the CLES, these two teachers identified constructivist aspects of the learning environment that they would like to improve. Using spiralling cycles of questioning, planning, implementing, collecting data and reflecting, the teachers developed strategies aimed at improving their learning environments. Based on the success of past studies (Sinclair & Fraser, 2002; Thorp, Burden & Fraser, 1994; Yarrow, Millwater & Fraser, 1997), this phase examined the effectiveness of using the Constructivist Learning Environment Survey as a tool that teachers could use to provide feedback information about, and to guide improvements in, their learning environments. Teaching strategies were implemented

over a 12-week period, during which time teachers attended a workshop, designed to assist them to learn how to keep and use a teaching journal (Daniels, 2002; Martin, 2000) that they were encouraged to use as a means of reflection.

During the 12-week intervention phase, weekly observations of the classes of the two case study teachers were used to determine whether they were using their reflections in their classroom practice and to provide encouragement and feedback during the process. Also, interviews were held with four learners from each class at the beginning, middle and end of the intervention phase to provide more in-depth information regarding their perceptions of the learning environment.

Analyses and results

Reliability and validity of the Constructivist Learning Environment Survey

In the first stage of the study, separate actual and preferred versions of four scales of the original Constructivist Learning Environment Survey (CLES) were administered to 1 843 learners in 43 classes. Analyses of these quantitative data were conducted to determine the validity and reliability of the instrument when used in South Africa.

Factor analysis

A principal components analysis with varimax rotation confirmed the *a priori* structure of the CLES comprising 24 items in either the actual or preferred form, with six items in each of the four scales of Personal Relevance, Uncertainty, Shared Control and Student Negotiation. The factor loadings obtained for the entire sample using the actual form of the CLES are shown in Table 1.

Table 1 Factor loadings for a modified version of actual form of the CLES in South Africa (N = 1 864)

Item No.	Personal Relevance	Uncertainty	Shared Control	Student Negotiation
1	0.35			
2	0.48			
3	0.41			
4	0.49			
5	0.45			
6	–			
7		0.30		
8		0.42		
9		0.32		
10		0.31		
11		0.44		
12		0.39		
13			0.40	
14			0.44	
15			0.46	
16			0.48	
17			0.49	
18			0.36	
19				0.45
20				0.51
21				0.51
22				0.40
23				0.51
24				0.38
% Variance	6.18	4.75	6.65	18.10
Eigenvalue	1.48	10.14	1.60	4.34

Factor loadings smaller than 0.30 have been omitted.

The factor analysis results in Table 1 supported the 24-item four-scale version of the actual form of the CLES. All the items had a loading of at least 0.30 on their *a priori* scale and no other scale, with the exception of Item 6 (whose loading was less than 0.30 on every scale). The percentage of the total variance extracted ranged from

4.75% to 18.10% for the subscales, with a total of 35.68%. The eigenvalues ranged between 1.14 and 4.34.

Internal consistency reliability

The internal consistency reliability (Cronbach alpha coefficient) was calculated to determine the extent to which each item measured the same construct. The internal consistency reliability of the actual and preferred versions of the CLES for each of the scales for two units of analysis (the individual and the class mean) are reported in Table 2. For the actual version of the CLES, reliability estimates for different scales ranged from 0.60 to 0.63 using the individual as the unit of analysis, and from 0.88 to 0.91 using the class mean as the unit of analysis. For the preferred version of the CLES, the scale reliability estimates ranged from 0.56 to 0.75 using the individual as the unit of analysis, and from 0.83 to 0.97 for the class mean as the unit of analysis. According to Nunnally and Bernstein (1994), a reliability estimate of 0.70 and above represents acceptable reliability. On the whole, therefore, we considered these values to be satisfactory for short scales containing only six items.

Discriminant validity

The mean correlation of a scale with the other scales in the CLES was used as a convenient index of discriminant validity and is reported in Table 2. For scales of the actual form of the CLES, the mean correlation of a scale with the other scales varied between 0.33 and 0.40 with the individual as the unit of analysis and between 0.56 and 0.68 with the class mean as the unit of analysis. For the preferred form of the CLES, the mean correlation of a scale with the other scales varied between 0.35 and 0.44 with the individual as the unit of analysis and between 0.62 and 0.76 with the class mean as the unit of analysis. These values generally could be regarded as small enough to confirm the discriminant validity of raw scores on the CLES, although some values are relatively high at the class level of analysis. This suggests that each CLES scale generally measures distinct aspects of the classroom learning environment. Moreover, the factor analysis attests to the independence of factor scores on the four CLES scales.

Ability to differentiate between classrooms

An analysis of variance (ANOVA) was used to determine the ability of the actual form of each CLES scale to differentiate between the perceptions of learners in different classes. The *eta*² statistics were calculated to provide an estimate of strength of the association between class membership and the dependent variable (CLES scale). The ANOVA results, presented in Table 2, indicated that each CLES scale is able to differentiate significantly between classrooms ($p < 0.01$). The amount of variance in scores accounted for by classroom membership (i.e. *eta*²) ranged from 0.15 to 0.26 for different scales. These figures suggest that learners perceived the learning environments of different mathematics classrooms quite differently.

Describing mathematics classrooms using the CLES

To provide information about how learners perceive the learning environment and how they would prefer it to be, we analysed their responses to the actual and preferred versions of the CLES. The average item mean (or the scale mean divided by the number of items in that scale) for learners' scores on the actual and preferred forms are tabulated in Table 3 and graphed in Figure 1 for the entire sample. Results suggest that learners would prefer a much more positive learning environment than the one actually perceived on each CLES dimensions (Figure 1). This finding has important practical implications for mathematics teachers and professional developers in South Africa, as it indicates that students would prefer a more student-centred learning environment.

The graphical profile depicted in Figure 1 indicates that learners would prefer activities associated with CLES items to occur with a frequency of between 'sometimes' and 'often' for each of the scales. However, Figure 1 also shows that the level of each CLES dimension

Table 2 Internal consistency reliability (Cronbach alpha coefficient) and discriminant validity (mean correlation with other scales) for two units of analysis and ability to differentiate between classrooms (ANOVA results) for the modified version of the CLES

Scale	Unit of analysis	Alpha reliability		Mean correlation with other CLES scales		ANOVA Eta^2
		Actual	Preferred	Actual	Preferred	Actual
Personal Relevance	Individual	0.61	0.56	0.35	0.44	0.23**
	Class mean	0.88	0.83	0.56	0.76	
Uncertainty	Individual	0.60	0.61	0.40	0.41	0.26**
	Class mean	0.90	0.93	0.68	0.74	
Shared Control	Individual	0.63	0.78	0.33	0.43	0.20**
	Class mean	0.90	0.97	0.61	0.75	
Student Negotiation	Individual	0.63	0.75	0.34	0.35	0.15**
	Class mean	0.91	0.94	0.68	0.62	

** $p < 0.01$

The sample consisted of 1 864 learners in 43 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.

Table 3 Average item mean, average item standard deviation and difference (effect size and results of MANOVA for repeated measures) between actual and preferred perceptions on each CLES scale for the individual and class mean as the units of analysis

CLES scale	Unit of analysis	Average item mean		Average item standard deviation		Difference	
		Actual	Preferred	Actual	Preferred	Effect size	F
Personal Relevance	Individual	2.64	3.48	0.75	0.71	1.15	6.45**
	Class mean	2.62	3.49	0.37	0.38	2.32	4.02**
Uncertainty	Individual	2.29	3.56	0.70	0.73	1.78	2.81**
	Class mean	2.23	3.59	0.36	0.43	3.44	4.18**
Shared Control	Individual	2.09	3.47	0.67	0.91	1.75	7.90**
	Class mean	2.06	3.47	0.29	0.49	3.62	4.35**
Student Negotiation	Individual	2.35	3.79	0.78	0.78	1.85	8.05**
	Class mean	2.31	3.78	0.39	0.35	3.97	4.80**

** $p < 0.01$

The sample consisted of 1 864 learners in 43 classes

perceived to be actually present is lower for every scale. The lowest average item mean in Figure 1 occurs for Shared Control, which is perceived to occur approximately 'seldom'.

Actual-preferred differences in classroom environment were explored by performing a one-way MANOVA separately for two units of analysis (the learner and the class mean). The multivariate test yielded significant results ($p < 0.01$) in terms of Wilks' lambda criterion, indicating that there were differences in the set of criterion variables as a whole. Therefore, the univariate ANOVA was interpreted for each CLES scale. The results reported in Table 3 indicated that a statistically significant difference ($p < 0.01$) between actual and preferred scores existed for each of the four learning environment scales for both units of analysis.

To estimate the magnitude of the differences between learners' scores on the actual and preferred forms of the CLES, effect sizes, in terms of the differences in means divided by the pooled standard deviation, were calculated (Thompson, 1998a; 1998b). The effect size for the different CLES scales, reported in Table 3, ranged between approximately one standard deviation (1.15) and one and three quarters standard deviation (1.85) for the individual as the unit of analysis, and between approximately two standard deviations (2.32) and four standard deviations (3.97) with the class mean as the unit of analysis. These results suggest large and educationally important differences between learners' perceptions of the actual and preferred environment. Descriptive analyses were used to provide graphical profiles (similar to the one drawn above) to individual teachers. The next section exa-

mines whether teachers were able to make use of information in these profiles to guide improvements in the constructivist orientation of their learning environments.

Using the CLES to guide and monitor changes to the learning environment

In the intervention phase we aimed to investigate whether teachers were able to make use of feedback information based on learners' responses to the CLES to develop and implement action research strategies to improve the environment of their classrooms. In addition, information was sought to determine whether journal writing was an effective tool to encourage teachers to reflect on their teaching. Teachers used graphical profiles, generated through learner responses to the CLES, as a focus for improving their learning environment. At the end of the intervention period, the CLES was readministered to learners to determine whether they perceived that teachers had made positive changes to the learning environment.

This section describes how two case study teachers used learner responses to the CLES to help them design strategies for improving the learning environment in their classes. The two case studies both involved female teachers, one who was teaching at the intermediate level (Grades 4 – 6) and the other at the senior level (Grades 7 – 9) in the Limpopo province of South Africa. The two case-study teachers both had class sizes ranging between 40 and 50 learners. Although they taught in schools that have electricity, they lacked many other resources and they each volunteered to be a part of the study because

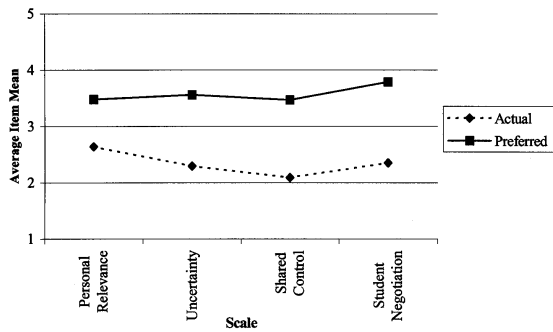


Figure 1 Average item mean for learners' actual and preferred scores on the CLES for the whole sample

they felt that it would assist them to teach in ways that were more constructivist and learner-centred.

The two teachers were each provided with the results of learners' responses to the actual and preferred versions of the CLES in the form of a graphical profile (see Figures 2 and 3). These were discussed with the teachers who were optimistic that they would be able to implement more constructivist teaching strategies, and improve their learners' perceptions of the learning environment over the 12-week intervention period.

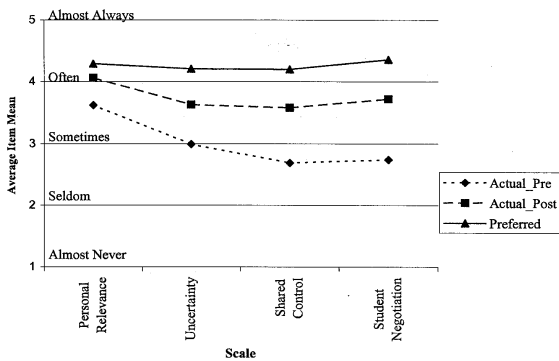


Figure 2 Average item mean for learners' actual pre-test, actual post-test and preferred scores on the CLES for Teacher 1

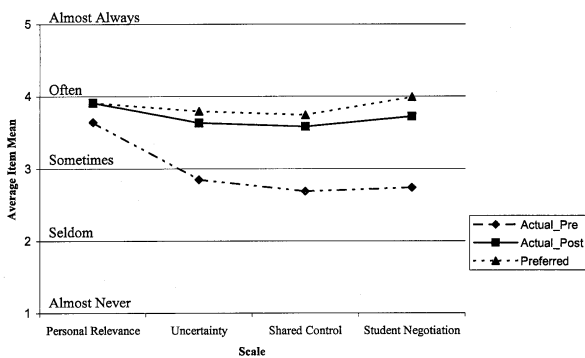


Figure 3 Average item mean for learners' actual pre-test, actual post-test and preferred scores on the CLES for Teacher 2

Learner scores on the pretest actual and preferred forms of the CLES were similar for both teachers. In both cases, learners would prefer that the dimensions assessed by the CLES occurred more than 'often' in their classroom, but learners perceived them actually occurring only less than 'sometimes'. Both of the teachers appreciated that learners' scores on the actual learning environment scales were below those that they would prefer and were keen to attempt to close the gap between the two.

Each teacher selected a particular dimension of the CLES that she felt was important. Teacher 1 opted to improve the Personal Relevance scale, whilst Teacher 2 chose the Student Negotiation scale. Using the wording of items within these dimensions as a guide, the teachers designed strategies that would assist them to improve their constructivist teaching practices. A summary of strategies used by the teachers for increasing the emphasis on each CLES dimension is presented below.

Strategies used by Teacher 1 to increase emphasis on Personal Relevance

Teacher 1 is currently teaching mathematics and science to learners from Grade 5 to Grade 7. She is in her fifties and holds a two-year primary teachers' certificate that was awarded in 1969. She has since studied privately to obtain a further diploma in teaching through distance education. She has been teaching for over 30 years and is still energetic and enthusiastic. She is eager to change from the more teacher-centred methods, with which she is accustomed, to more learner-centred methods. Though nearing retirement, she is dedicated to her job and is keen to be observed by the researcher. This teacher's mathematics class had 46 learners arranged into groups of four or five learners.

Teacher 1 decided to attempt to improve Personal Relevance using the following two strategies: discussing and impressing on learners the importance of mathematics to their future lives; and making the problems that she presented to learners more relevant to their daily lives.

The teacher considered that a key aspect of the Personal Relevance scale was the importance of mathematics to the future of the learners. To give learners an appreciation of the role of mathematics in their future, the teacher decided that she would give the learners the task of asking their parents about the role of mathematics in their lives. In addition, this teacher sought to integrate the mathematics lessons into a language lesson by asking learners to write a composition entitled 'The importance of mathematics in our daily life and our future'. In response, one learner wrote: "Mathematics is the foundation subject to all careers. If you want to be accountant, mathematics must be studied in Form 4 and Form 5. Plumbers must be good at figures so that they can fit pipes correctly." Another learner wrote: "In cooking, we are using mathematics for measuring flour. We are always using mathematics when we do sewing."

It would appear that the teachers' emphasis on the importance of mathematics to learners made quite an impact on the learners. Interviews with learners indicated that the discussions with parents and in groups helped learners to regard their mathematics classes in a more positive light. The teacher noticed that learners were more eager to have homework on a daily basis.

In an attempt to increase the learners' perceptions of the level of Personal Relevance, the teacher decided that it was important to make the mathematics that was taught them more related to their daily lives. In the past, she had not paid much attention to the types of problems that she presented to learners and was often content to use examples that might have lacked relevance to the learners. To address this, she tried to give learners exercises that involved their surroundings. For example, when teaching measurement, she provided opportunities for learners to measure distances around buildings and classrooms. She also involved learners in practical examples, such as measuring their own heights using metre sticks or rulers.

During lessons that involved the drawing and interpretation of graphs, the teacher made the exercise more relevant by getting the

learners to collect the data themselves. She also ensured that, if she used graphs that were not constructed by the learners, the graphs would be related to their everyday lives, such as the graphs found in newspapers that show rainfall.

A big step for this teacher was to implement her ideas using group work, something with which she had not had much experience. As a first step, she changed the way in which desks were arranged in her classroom so that learners were no longer facing the chalkboard, but were seated in groups of four or five learners. According to this teacher, the introduction of group work was the most difficult aspect of the intervention period. Learners were much noisier than they had been in the past and the noise created during mathematics classes could be heard along the corridors, thus causing the teacher to be most concerned about the reactions of her fellow teachers. In addition, she found that learners tended to talk over each other, without realising that they had to give others an opportunity to have their say.

According to the teacher's journal, one of the biggest problems that she experienced during this time was ascertaining whether the learners had learned what they were supposed to. She found that, without the use of formal tests, she had difficulty determining which learners were making adequate progress or had grasped a particular concept.

It was at this stage of the intervention period that the teacher required the most support. Without guidance, support and encouragement at this stage, it is felt that the teacher would have stopped using the ideas and strategies that she had selected. According to the teacher during discussions with the researcher, she was tempted on numerous occasions to revert back to her more teacher-centred ways as she felt that learners were easier to control using these methods and that it was easier to assess learners' progress.

Her persistence with the use of groups appeared to have paid off. Towards the end of the 12-week intervention period, the teacher used groups to make good use of the limited resources, to engage the learners in activities, and to report learners' findings to the class.

Examining the success of Teacher 1's strategies

The teacher gradually became more confident with the use of groups and developed management strategies that helped her to control the class. She developed strategies that helped her to maintain a healthy noise level and assisted the learners to learn to give each member of the group an opportunity to have their say without talking over them. Interviews with learners indicated that they appreciated the use of activities that involved them in their learning and the use of group activities.

Table 4 and the graphical profile shown in Figure 2 provide the results of the post-test administration of the actual form of the CLES. The graphical profile also reports the information for learners' actual pretest and preferred scores. These results indicate that learners perceive a more favourable learning environment for all scales on the post-test relative to the pretest. *T* tests for paired samples were calculated to examine differences between the pretest and post-test scores. A statistically significant ($p < 0.01$) improvement in learning environment scores for all four CLES scales and the effect sizes for differences between pre-test and post-test scores ranged between 0.94 and 1.60 standard deviations for different scales.

These results indicate a substantial improvement in learner scores for all CLES scales. It would appear that the nature of the changes that the teacher attempted to make to her learning environment and her use of group work led to improved levels of Uncertainty, Shared Control and Student Negotiation. The results shown in Table 4 and Figure 2 indicated that the learning environment perceived by learners at the end of the intervention period is close to the learning environment that they would prefer.

Strategies used by Teacher 2 to increase emphasis on Student Negotiation

Teacher 2 teaches Grade 6 mathematics in a different school from the

first teacher. She has teaching experience of 21 years and holds a primary teachers' certificate, which she was awarded in the 1970s. She is presently attempting to improve her qualification through distance education. She has attended in-service training workshops, that were organised during the apartheid era, on teaching mathematics in primary schools. The mathematics classes that she is teaching are composed of around 50 learners in each of the classes.

Table 4 Average item mean, average item standard deviation and difference (effect size and paired *t* test result) between pre-test and post-test scores on each CLES scale for Teacher 1

CLES scale	Average item mean		Average item standard deviation		Difference	
	Pre-test	Post-test	Pre-test	Post-test	Effect size	<i>t</i>
Personal Relevance	3.49	4.21	0.69	0.57	1.14	5.27**
Uncertainty	2.96	3.91	0.78	1.24	0.94	4.93**
Shared Control	2.79	3.75	0.60	0.80	1.37	7.48**
Student Negotiation	2.73	3.86	0.80	0.61	1.60	8.08**

** $p < 0.01$

The sample consisted of 46 learners in Teacher 1's class

Teacher 2 elected to work on strategies that would help to improve the level of Student Negotiation in the classroom. To improve this dimension, she decided to place more emphasis on discussions between learners during lessons. To facilitate discussions between learners, the teacher arranged the desks into groups of six, enabling learners to face each other rather than the chalkboard.

Even though the teacher felt that there was merit in allowing time for learner discussions, she was most concerned that the learners would be disruptive and all talk at once. One of her biggest concerns was the possibility of creating a noisy classroom. The researcher felt that this teacher was most ambitious in her decision to strive to improve the Student Negotiation scale and in the strategies that she implemented to do this.

To facilitate discussion, the teacher tried to provide opportunities for learners to work in groups. At the beginning of the intervention period, she would give a problem to the whole class, which learners would solve individually. She then got them to discuss how they had solved the problem and arrived at the solution. As a group, they were required to decide on the best explanation and to report back to the class.

Over a period of time, she gradually modified this strategy as she found that some groups were struggling with problems. She started to present different problems to different groups, particularly if some learners appeared to be having difficulty in solving a particular problem.

Observations of such sessions indicated that, whilst the groups remained the same, the teacher ensured that the reporters changed from time to time. She encouraged the learners to report back their findings using the chalkboard and invariably the explanations of the different groups would be slightly different.

Examining the success of Teacher 2's strategies

The teacher's prediction of classroom disorder, in many ways, was true, particularly at the beginning of the 12-week intervention period. The learners were not used to being seated in groups and had not experienced lessons in which they were encouraged to discuss their ideas with their peers. According to the teacher's journal, she felt that she lacked control because of the amount of noise in the room. As with the first teacher, this teacher required much encouragement and support

to persist with her selected strategies. It appeared that the learners were not aware of what was required of them at all times and, as a result, became restless and noisy. This, in turn, created an apparent lack of control on the part of the teacher. Discussions with the researcher, based on her journal entries, led to the preparation of worksheets and other learning support materials for individuals and groups to guide them during lessons. Interviews with the teacher about the introduction of the learning support materials indicated that those learners without learning support materials misbehaved more than learners with materials in their possession. Interviews with learners indicated that they felt that the learning support materials helped them to understand what they were doing and learning.

Although the teacher was generally pleased with the way in which her learners had interacted during such lessons, she indicated in her journal that she had encountered difficulties in managing her time effectively and that she was often left without the opportunity to conclude the lesson as well as she would have liked. She found that, for some lessons, there was not enough time to finish work she had set out to accomplish and, in these cases, she had to set it for homework. She did not stop using the strategies. Because not all groups could report because of time constraints, she changed the way in which the learners reported each day. Learners who did not report one day were then supposed to be the first group to report the next day. During discussions, she did not have experience discipline problems related to learners trying to talk at the same time as other learners. Instead, learners were listening to colleagues and then answering one after the other.

At the end of the 12-week period, the CLES was administered again to learners as a post-test. The results for the differences between pre-test and post-test scores on the CLES are reported in Table 5 and presented graphically in Figure 3. Figure 3 also includes the initial

Table 5 Average item mean, average item standard deviation and difference (effect size and paired t test result) between pre-test and post-test scores on each CLES scale for Teacher 2

CLES scale	Average item mean		Average item standard deviation		Difference	
	Pre-test	Post-test	Pre-test	Post-test	Effect size	t
Personal Relevance	3.64	3.91	0.67	0.56	0.44	3.71**
Uncertainty	2.85	3.47	0.78	0.69	0.84	4.28**
Shared Control	2.56	3.40	0.82	0.69	1.11	5.38**
Student Negotiation	2.35	3.59	0.98	0.68	1.49	5.95**

** $p < 0.01$

The sample consisted of 56 learners in Teacher 2's class

preferred scores on the CLES. The results for *t* tests for paired samples (reported in Table 5) indicated a statistically significant ($p < 0.01$) improvement on learner scores for all four CLES scales. The effect size for pre-post differences for Teacher 2 ranged between 0.44 and 1.49, with learners perceiving a more favourable learning environment on all four CLES scales. As with Teacher 1, the teacher's attempt to improve one of the learning environment scales was accompanied by an improvement in learners' perceptions of all four scales. It would appear that the introduction of group work, during which learners were encouraged to negotiate their answers and the way in which they solved problems, led learners to feel that there was more Personal Relevance, Uncertainty and Shared Control in the classroom. Observations and interviews with learners and the teacher also support this finding. For example the teachers tended to use examples and generate discussions about topics that were familiar to learners. The learners indi-

cated that they enjoyed the discussions that were generated during these group opportunities and that, since this strategy was introduced, they were experiencing greater enjoyment of mathematics.

In many ways, the results for the two teachers are similar. In both cases, there were sizeable pre-post changes in CLES scores, not only for the scale for which they were attempting to increase emphasis, but also for the other three CLES scales. The similarity in the pattern of changes could be attributed to the strategies employed by the teachers, as both involved the introduction of group work and discussions in their mathematics classes. It is interesting to note that, in both cases, the post-test actual scores are close to what learners would prefer to happen in their mathematics classes.

Using journals as a tool for reflection

A further aim of the study was to explore whether the use of journals (Daniels, 2002; Martin, 2000) is a useful tool to help teachers to improve the learning environment. Throughout the 12-week intervention period, the two teachers in our study were asked to keep a daily journal in which they wrote about and reflected upon strategies they were implementing in their classrooms. The teachers used the journals to reflect on issues such as: "Today I failed to allow the freedom that would allow my learners to ask me questions freely. I must see to it that I practice having a healthy classroom atmosphere that allows the learners to express themselves freely." In most cases, the teachers wrote about issues with which they were confronted, such as: "Today I failed to facilitate a group discussion because learners seemed to be talking and discussing irrelevant things instead of the geometric figures which were given to them." The teacher then wrote about a strategy that could be used to overcome this issue in the next lesson. "The solution that I will use to try to guard against irrelevant discussions during group work is to have worksheets prepared for the different groups."

Teacher 2, who experienced difficulty with time management, wrote: "How can I control the time so that, at the end, I am able to say that my learners have completed this section of the syllabus?" This is a problem that was experienced by the two teachers because, when the inspector visited the school, he would expect to see exercises written by the learners and the scope of the syllabus that had been covered. To address the problem, the teacher wrote: "The solution is that, as the group talks, they must write (with the scribe keeping one record for the whole group). This will involve group assessment and the allocation of marks."

Interviews were conducted with both teachers to determine whether they felt that the use of journals was advantageous. When asked whether they felt that the journals had helped them to improve their professional skills and, if so, how they knew, the teachers generally agreed. One teacher stated:

"Writing a journal is like doing lesson preparation in a reflective way because you are writing about what happened, and you are being introspective about all that you did during the lesson."

The other teacher responded:

"I know that I have improved because I am no longer teaching in the same way that I was taught at the college. I allow my learners to talk amongst themselves, to ask me questions and to assess themselves in their groups. I am also not feeling challenged when learners ask questions."

Both teachers agreed that the use of journals was useful, although they complained that it was time consuming. Generally the teachers did not appreciate the value of journal writing, just as they did not appreciate daily lesson preparation, feeling that it was time consuming. Both teachers were already pressed for time with more than 80 learners whose work they needed to mark and report on. Throughout the intervention period, the teachers required constant support and encouragement from one of the researchers to make entries into and use the journals.

Despite the reluctance to write the journals, writing appeared to keep the teachers on track and thinking about possible solutions. Whilst teachers were reluctant to use their journals at the beginning of

the study because of the additional work, they did find them useful in guiding their reflection and in helping to successfully change teaching practice.

Discussion and conclusions

A major contribution of the present study was the modification and validation of a questionnaire (the Constructivist Learning Environment Survey, CLES) to monitor the development of constructivist learning environments in intermediate and senior schools in South Africa. A preferred and actual version of the CLES was validated for use in South Africa among 1 864 learners in 43 classes in six schools.

Careful modification and pilot testing of the CLES (developed originally in the West) ensured its suitability for mathematics classrooms in South Africa. Principal components analysis with varimax rotation suggested a strong factor structure for a 24-item, four-scale version of the CLES. The internal consistency reliability of the modified CLES was found to be satisfactory at both the individual and class mean levels of analysis for both the actual and preferred forms. Discriminant validity indices (mean correlation of a scale with other scales) indicated that there was some overlap between the scales, particularly for the preferred form of the questionnaire. The use of ANOVA indicated that each CLES scale was able to differentiate between the perceptions of learners in different classes. Overall, the results suggested that the CLES, when modified to suit the South African context, is valid and reliable. The results are comparable to those for other countries where the CLES has been used, including Taiwan and Australia (Aldridge *et al.*, 2000), Korea (Kim *et al.*, 1999; Lee & Fraser, 2002) and the US (Dryden & Fraser, 1998; Johnson & McClure, 2002; Nix *et al.*, 2003). These results suggest that researchers and teachers can be confident about using the modified version of the CLES in mathematics classes in South Africa in the future.

Descriptive analysis was used to provide information about the constructivist nature of mathematics classes in the Limpopo province of South Africa. The results indicated that learners preferred a learning environment that was more positive than the one that prevailed for all four CLES scales. These results are consistent with previous research (Fraser, 1998) but indicated unusually large effect sizes for actual-preferred differences.

In the second phase of the study, we examined whether teachers were able to make use of feedback provided through learners' responses to the CLES to improve their constructivist learning environments. The results reported in this article indicate that teachers were able to use feedback from the CLES to design teaching strategies that were successful in improving the level of one of the CLES dimensions. Teacher 1 used the following two strategies: discussing the importance of mathematics to learners' futures; and making problems more relevant to learners' daily lives. Teacher 2 planned to work on strategies to improve the level of Student Negotiation in the classroom. She decided to facilitate discussions between learners and to arrange desks into groups. Her strategies made her aware that, if a group of learners do not have enough resource materials or worksheets, they are likely to resort to making more uncontrolled noise.

The results for the pre-post changes indicated that both teachers were successful in improving learner scores on the CLES. In both cases, there were statistically significant improvements ($p < 0.01$) on CLES scales between the pre-test and post-test. For both teachers, the post-test actual scores were close to what the learners would prefer to happen in their classes.

Over a 12-week intervention, the researcher supported the teachers with journal writing and its interpretation as they maintained daily records of their teaching in a reflective way. In these journals the teachers recorded their problems and possible solutions. The results of the study indicated that the use of journals helped the teachers to keep on track and to think about possible solutions to problems, as well as encouraging them to reflect and plan future activities. Although both teachers complained that journal writing consumed a lot of time, they still valued the use of journal writing and felt that the journals were ad-

vantageous. Therefore this study supports the usefulness of introducing journal writing in teaching and learning situations.

The results of the study supported the efficacy of using the Constructivist Learning Environment Survey to provide feedback that can guide teachers in changing their classroom towards a more constructivist orientation. The results of this study are consistent with past studies that have used learning environment assessments to guide improvements in the learning environment (Sinclair & Fraser, 2002; Yarrow *et al.*, 1997).

Our study provides teachers with a means for being reflective practitioners and researchers within their own classrooms, thus giving them some skills for improving their teaching in the future. The use of journals as a means of recording teachers' experiences would also appear to be an effective means of encouraging teachers to reflect on their teaching. Using an action research cycle that incorporated the use of a journal, the two teachers both implemented sizeable changes in their teaching strategies as they incorporated more constructivist methods.

In our experience, teachers who have taught for a number of years often resort to their old ways of teaching rather than continuing with new strategies. Throughout the study, one of the researchers was close at hand to encourage teachers to keep trying; it is felt that this contributed to the teachers' success. The effectiveness of journal writing for reflective purposes found in our study suggests the desirability of introducing journal writing in the training of teachers.

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