

Exploring South African Grade 11 learners' perceptions of classroom inquiry: validation of a research instrument

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Abstract

This paper discusses the adoption and validation of a research instrument, on determining learners' levels of perception of classroom inquiry based on data collected from South African Grade 11 learners. The Learners' Perception of Classroom Inquiry (LPCI) instrument consists only of Likert-type items which rank activities according to how often they occur. Learners' rankings were used to predict extent to which they are engaged in principles of scientific inquiry in the laboratory. Other data sources included expert and learner interviews for purposes of content validity and corroboration of learners' LPCI responses respectively. Correlation analysis revealed that all five inquiry facets correlate substantially with the total score of all the constructs. Results provide evidence of relevant satisfaction that relates mainly to the instrument having passed the test in terms of face, criterion, construct and content validity. On a wider scale and in larger populations, the instrument can be used with confidence.

Keywords: scientific inquiry, learners' perceptions, inquiry learning, inquiry teaching learning environment

Introduction

The teaching and learning of science through inquiry has been a major focus in science education for more than a century (DeBoer, 1991). Evidently, the past ten years have witnessed a renaissance of interest in scientific inquiry. This shown by both an increase in volume of research on teaching and learning through inquiry appearing in science education journals and the advocacy for inquiry by contemporary school science curricula reform documents (see, Abell & Lederman, 2007; Campbell, Abd-Hamid, & Chapman, 2010; Flick & Lederman, 2004). Advocacy for inquiry is partly driven by the fact that over the years numerous studies have repeatedly shown that although the development of learners' knowledge about scientific inquiry is an important science education curriculum goal, most secondary school learners continue to show naive understandings (Abd-El-Khalick & Lederman, 2000a, 2000b; Lederman & Niess, 1997). Scientific inquiry is both about doing science and developing learners' understandings of the processes undertaken by scientists in developing scientific knowledge, that is, the nature of scientific inquiry (NOSI) (Flick & Lederman, 2004). There is belief that engagement of learners in inquiry-based investigative activities can result in their improved understanding of NOSI (Wong & Hodson, 2008). This is especially so when the activities are explicitly designed to develop learners' NOSI understandings.

In line with international trends and fashions, South Africa introduced a new secondary school science curriculum in 2006. The curriculum advocates for teaching and learning of science through inquiry (Department Of Education, 2005). The National Curriculum Statement (NCS) Statement for Physical Sciences requires that this be done through engagement of learners in inquiry-based scientific investigations (NCS, Department of Education, 2005). This entails providing learners with opportunities to; use tools, propose problems for investigation, ask questions, formulate hypotheses, design procedures, collect data, analyse data, process answers and explanations, predict and communicate results as well as identify assumptions and use of logical and critical thinking (Campbell, et al., 2010; Hofstein, Navon, Kipnis, & Mamlok-Naaman, 2005; Songer, Lee, & McDonald, 2003). The investigative skills the NCS Subject Statement for Physical Sciences seeks to test learners on are listed as abilities to: (1) plan investigations, (2) conduct investigations, (3) interpret data to draw conclusions (4) solve problems and (5) communicate and present information and scientific arguments. The investigations contribute 40% to the total continuous assessment mark which is school-based, a huge weighting, illustrating the importance attached to engagement of learners in scientific inquiry. However, although the intentions of the new curriculum are noble, nothing is known to date about the extent to which learners are actually engaged in inquiry as a result of its implementation.

Falling within the realm of classroom learning environments research (Fraser, 1998a), the study we report here is the first of its kind investigating the extent of implementation of scientific inquiry in an African secondary school classroom. It is also the first to adopt and validate the Principles of Scientific Inquiry-Student (PSI-S) instrument (Campbell, et al., 2010) in Africa. Basically, this instrument measures learner perceptions of the extent to which they experience inquiry during science lessons. According to Fraser (1998a), learner perceptions of their classroom environment and experiences can be used as reliable indicators of teacher instructional practices. An understanding of the classroom learning environment is important for both the theory and practice of science education. Specifically, this paper reports the adaptation and validation of the Principles of Scientific Inquiry-Student (PSI-S) instrument (Campbell, et al., 2010) based on data collected from a class of South African Grade 11 learners at a school in Johannesburg, Gauteng Province, South Africa. It evaluates the confidence with which the instrument can be used, on a wider scale, to assess learners' perceptions of their experiences of scientific inquiry within the context of South African science classrooms.

Learning environment research instruments

During the past five decades, research into learning environments has produced a large variety of instruments. Essentially, learning environment research instruments are questionnaires designed to capture quantitative and/or qualitative data about learners'/teachers' assessments of the "...social, psychological, and pedagogical contexts in which learning develops and which affect students' achievements and attitudes" (Telli, den Brok, Tekkaya, & Cakiroglu, 2009, p.110). According to Fraser (1998b), the development of instruments designed to measure learners' perceptions of their learning environments started in the 1950s and gained momentum in the early 1970s. Among the first instruments to be developed and widely used were: the Learning Environment Inventory (LEI), first developed by Anderson (1971); and the Classroom Environment Scale (CES) (Moos & Trickett, 1974). Since then, these instruments have been gradually refined and modified into a large number of varieties allowing researchers to select, adapt and/or adopt them to suit their contexts and needs. Among the instruments to have emerged are the: Science Laboratory Environment Inventory (SLEI) (Fraser, Giddings, & McRobbie, 1995); Chemistry Laboratory Environment Inventory

(CLEI) (Wong & Fraser, 1995); and Questionnaire on Chemistry-Related Attitudes (QOCRA) (Wubbels & Brekelmans, 1998). These instruments are of relevant to the study we report here because they were designed for studying science laboratories in senior high schools and universities.

According to Campbell et al. (2010) several instruments have been developed to assess the degree to which a particular classroom's climate is consistent with constructivist epistemology and pedagogy. These instruments include: Constructivist Learning Environment Survey [CLES] by Taylor, Fraser and Fisher (1997); and Constructivist Online Environment Survey [COLLES] by Taylor and Maor (2000). The instruments elicit learners' perceptions of the constructivist nature of their classroom-learning environment and can be used to help teachers reflect on their epistemological assumptions and reshaping their teaching practices. An instrument of relevant interest is the Science Teacher Inquiry Rubric [STIR] (Beerer & Bodzin, 2004), which has been used to identify and classify inquiry activities for each of the five essential features of classroom inquiry, based on the amount of learner self-direction and direction from materials ([NRC], 2000). The five essential features of inquiry are: (1) planning investigations, (2) conducting investigations, (3) interpreting data to draw conclusions (4) solving problems and (5) communicating and presenting information and scientific arguments. Although the STIR can be used to identify and describe these essential features of classroom inquiry, it does little to capture learners' perceptions of the nature and extent to which they are engaged in scientific inquiry, i.e. assess the extent of open endedness of inquiry.

From our survey of the literature and according to our judgement, none of the instruments we have so far described can be used to determine the extent to which learners are engaged in scientific inquiry by eliciting teacher and/or learner perceptions of the learning environment. We believe that, the recently developed Principles of Scientific Inquiry-Student (PSI-S) instrument by Campbell, et al. (2010) can be a useful tool in producing information that can be used to quantitatively describe the extent of open endedness of inquiry. As already noted, while this is so, no study has been done on the African continent specifically investigating the extent to which learners are engaged in scientific inquiry using this instrument. Our effort was to investigate the validity of this instrument within the context of South African science classrooms. For this study, we adopted the PSI-S instrument and named it the Learner Perceptions of Classroom Inquiry (LPCI) instrument (see, Appendix A).

Theoretical Framework

Inquiry in school science

According to Hofstein and Lunetta (2004), scientific inquiry (as practiced by professional scientists) refers to the various ways of studying the natural world, asking questions, proposing ideas, collecting evidence to justify assertions and explanations and communicating results. School science inquiry is seen as similar to the inquiry done by professional scientists as learners also investigate the world, propose ideas and justify explanations based on collected evidence. Chinn and Malhotra (2002), however, argue that school based inquiry is cognitively and epistemologically different from authentic scientific inquiry (research done by scientists). It is noteworthy that the cognitive tasks needed for authentic science are more demanding than what is required for school science. Authentic scientific inquiry is a complex activity employing expensive equipment, elaborate procedures and theories requiring highly specialized expertise for data analysis. Schools lack both the resources and time to engage in authentic science. Epistemologically, school science is simple inquiry aimed at uncovering simple observable regularities whereas authentic science aims at uncovering new theoretical

models and revising existing ones. When examining inquiry in the context of school science therefore, it should always be borne in mind that this inquiry is within the cognitive and epistemological boundaries of school science.

Within this realm, learners' classroom experiences can be examined through a lens of the nature, form and extent of inquiry woven through the teaching and learning activities. Vhurumuku, Holtman, Mikalsen, & Kolstoe, (2004) describe school science learning activities as belonging along a continuum ranging from closed inquiry oriented to open ended of inquiry. Generally, teaching and learning experiences can be described as closed inquiry, when they are characterized by being; teacher centred, expository, verificationistic, and transimissionistic. In closed inquiry laboratories, learners are given little or no opportunities to propose problems for investigation, ask questions, formulate hypotheses, design procedures, process answers and explanations, predict and communicate results as well as identifying assumptions, use logical and critical thinking and engage in argumentation. According to Vhurumuku (2011) closed inquiry laboratories are associated with such activities as: learners following step-by-step instructions from the teacher or laboratory guide; learners are required to answer specific questions -posed by the teacher or laboratory manual; problems that come up in class are not investigated; there is no search for alternative explanations to phenomena; teacher lectures to the class or to groups of learners within the class; low levels of learner-learner and learner-teacher argumentation; outcome of experiment known prior to the experiment; and use of textbook or teacher explanations for observed phenomena. To the contrary is open ended inquiry, which is learner centred and associated with such activities as: learners formulating their own problems and questions for investigation; seldom following step-by-step instructions from the teacher or laboratory guide; investigating problems that come up in class; offering alternative explanations to phenomena; high levels of learner-learner and learner-teacher argumentation; and outcomes of experiment being unknown prior to the experiment (Domin, 1999; Shiland, 1999). In general, the greater the latitude given to learners to practice these activities the more open-ended the inquiry; i.e. the larger the extent of inquiry.

The various teaching approaches or styles used in science, such as, demonstrations, guided discovery, problem solving and open-ended investigations can be located along the surfaces of a continuum whose poles are closed inquiry oriented to open ended of inquiry. In demonstrations, the teacher or the learner (s) handle or manipulate of laboratory equipment apparatus and/or materials and make observations mainly for purposes of illustrating some theoretical or practical phenomena. Because in most science lessons demonstrations are largely teacher centred and verificationistic, the extent to which learners can experience inquiry is limited. This is in spite of the fact that during demonstrations, teachers can provide learners with opportunities to think critically by asking questions that encourage thought and use of prior knowledge (Hanson & Wolfskill, 2000). In guided discovery, also called guided-inquiry, learners are led to an understanding of scientific concepts by performing experiments or exercises whose outcomes are already known to the teacher (Domin, 1999). The teacher formulates the problem for the investigation, or problem is taken from a laboratory manual or handout, and gives students the procedure to follow, and what observations to make and record. In many cases a table for recording data is provided. Through post-laboratory discussions or questions answered following the practical activity, learners are led to "discover knowledge or new concepts".

To Domin (1999), problem solving differs from discovery in that in problem solving learners make use of the knowledge they have acquired whereas in discovery learners acquire

knowledge. While the discovery approaches have learners' acquisition of scientific knowledge as the main focus, problem solving has the development of skills as its main agenda. During problem solving, teacher assistance to the learners is kept minimal. In most laboratory situations, the teacher already knows the solution to the problem. The laboratory is seen as a place where learners can learn the scientific processes of problem solving, observation, hypothesizing, manipulation, interpretation, etc. (DeBoer, 1991; Hodson, 1996). Whereas in problem solving the outcome of the experiment or exercise is normally predetermined that outcome is undetermined for more open-ended investigations. For both approaches however the procedure for carrying out the experiment is determined by the learners. In open-ended investigations, learners are given greater freedom to ask questions, design and plan experiments and decide on how they are going to record, interpret and communicate results.

The South African curriculum context

In order to fully understand the context in which this validation was undertaken, it is important to briefly examine the South African curriculum. The forerunner to the current National Curriculum Statement (NCS) at Further Education and Training (FET) phase, Curriculum 2005, prescribed learners to do eight (8) experiments in Physical Science, four in Physics and four in Chemistry. These were verificationistic experiments where teachers were told by the Department of Education to conduct from certain sections of the syllabus and provide marks which were part of the School Based Assessment (SBA). Learners were to follow the problem to be investigated, the apparatus to be used, the procedure and the answer to the problem of which all were given by the teacher or by a worksheet. However, the new South African science curriculum is guided by assessment which focuses on clearly defined learning outcomes (Department Of Education, 2005). A learning outcome is a statement of intended result of teaching and learning. Learning Outcomes describe knowledge, skills and values that learners should acquire as a result of going through a curriculum. They describe what the learner should be able to do. The new Physical Science curriculum has three learning outcomes, which are.

Learning Outcome (1), focusing on scientific inquiry and problem-solving skills reads:

The learner should be able to use process skills, critical thinking, scientific reasoning and strategies to investigate and solve problems in a variety of scientific, technological, environmental and everyday contexts (Department Of Education, 2005);

Learning Outcome (2), focusing on constructing and applying scientific knowledge, which reads:

The learner should be able to state, explain, interpret and evaluate scientific and technological knowledge and can apply it in everyday contexts (Department Of Education, 2005); and

Learning Outcome (3), focusing on the nature of science and its relationship to technology, society and the environment says:

The learner should be able to identify and critically evaluate scientific knowledge claims and the impact of this knowledge on the quality of socio-economic, environmental and human development (Department Of Education, 2005).

In the study which the instrument is intended to be used only Learning Outcomes (1) and (3) are of interest since they relate to the nature of scientific inquiry (NOSI). It is noteworthy, that the skills and processes which learners are expected to use and develop in their study of the Physical Sciences are similar to those practiced by professional scientists in their daily activities. Inherently, South Africa's new science curriculum assumes that by "doing inquiry" learners will come to understand the NOSI. There is nowhere in the curriculum where an

explicitly understanding of NOSI is mentioned. Research has shown that doing inquiry does not necessarily translate into understanding NOSI (Bell, Blair, Crawford, & Lederman, 2003; Clough & Olson, 2004; Wong & Hodson, 2008). What then exactly happens in South African classrooms with regards to implementation of the new curriculum and learners' understandings of NOSI? This is an interesting research issue.

While LO1 appears implicit about developing learners' NOSI understandings a closer examination of LO3 shows that learners understanding of the NOSI is a pre-requisite for the achievement of this outcome. In order for learners to "identify and critically evaluate scientific knowledge claims" they must of necessity have an understanding of the NOSI. Of course the translation of this intention into reality might be entirely dependent on teachers own interpretation of the outcome which in turn depends on their own understandings of the NOSI. Learning Outcome 1 is implicit in that there is an underlying assumption that learners will learn about the NOSI by simply participating in investigative activities. This is similar to the cognitive apprenticeship approach which is an implicit teaching approach based on the assumption that learners can understand inquiry through doing inquiry (Sandoval & Reiser, 2004). Hodson and Hodson (1998) have called it 'enculturation'; initiating students into the beliefs, values, practices and styles of discovery of the scientific community by doing science.

Research questions

The PSI-S instrument is designed to measure learner perceptions of the frequency of occurrence of the five principles of scientific inquiry, namely (1) framing research questions, (2) designing investigations, (3) conducting investigations, (4) collecting data, and (5) drawing conclusions (Campbell, et al., 2010). These are the same principles advocated for by the South African NCS for Physical Sciences (Department Of Education, 2005). Validity is about gathering evidence that can support the correctness and appropriateness of interpretations and inferences that can be made from the responses to an assessment instrument (Moskal & Leydens, 2000). Our investigation of the validity of the PSI-S instrument was guided by the following questions:

- i. How well do the five principles of scientific inquiry predict learners' perceptions of classroom inquiry?
- ii. How much variance in learners' perceptions of classroom inquiry can be explained by scores on these five principles of scientific inquiry?
- iii. Which of these five principles of scientific inquiry is the best predictor of learners' perceptions of classroom inquiry?

To answer these questions, standard multiple regression analysis was used. It involved all the independent variables (sum of scores for each of the five principles of scientific inquiry) being entered into the equation at once.

Methodology

Learner Perceptions of Classroom Inquiry (LPCI) instrument

The LPCI instrument was adopted from Campbell, et al., (2010). Essentially the instrument measures learner perceptions of the extent to which they experience inquiry during science lessons. In its original form, the instrument consists of 20-items separated into five parts (each with four items), each representing a category of the practice of scientific inquiry namely asking questions/framing of research questions, designing investigations, conducting investigations, collecting data and drawing conclusions. The response alternatives for the items are based on a five-point Likert scale with responses ranging from Almost never to Almost always. The activities are ranked according to how often they occur. Learners'

rankings are then used to determine the extent to which they are engaged in the principles of scientific inquiry in the laboratory or classroom. Examples of items on the questionnaire are: “I formulate questions which can be answered by investigations” and “I determine which data to collect. As mentioned earlier, the instrument was chosen because there is close alignment between instrument items with practical and investigative skills advocated by the NCS Subject Statement for Physical Science namely: (1) planning investigations, (2) conducting investigations, (3) interpreting data to drawing conclusions (4) solving problems and (5) communicating and presenting information as well as raising scientific arguments.

The instrument has been found to be internally consistent with high reliability estimates established after both Cronbach alpha reliability test estimates and Exploratory Factor Analyses were performed on it (Campbell, et al., 2010) with 130 secondary school science learners from one Western State, in the USA. However, issues of face, content, criterion and construct validity within the South African context are critical and have to be addressed. It is necessary to also validate the core questions in terms of the suitability of language and their understandability, since the language proficiency of the sampled learners in the intended study is expected to be generally low. The language proficiency of South African learners is expected to be generally low because English Language is not the learners’ first language. It is either the third or fourth and not even the second language since South Africa has a plethora of official languages (eleven to be precise). Readability concerns for the LPCI are thus addressed by this validation process.

Sampling and administration

A school located in Johannesburg (within 50km radius) in the Gauteng Province of South Africa was purposefully and conveniently sampled (Patton, 1990) for its proximity and accessibility to the researchers for piloting the instrument. The school is functional in terms of availability of teaching and learning resources for Physical Science and class sizes. Learners from two Grade 11 Physical Science classes (n=90) were used to validate the instrument by completing the instrument. For inferential statistics, for example, Multiple Regression to be performed, Pallant (2005) recommends that about 15 subjects per predictor are needed for a reliable equation hence the sample met the assumptions for the robust statistics. All the learners completed the LPCI instrument. Ten learners, five from each class were interviewed in two focus group interviews using a semi-structured format (Merriam, 1998) for purposes of corroborating their LPCI responses and to get deeper understandings of learner responses. Learners were asked questions relating to what actually happens in the laboratory when conducting investigations. Learners were asked to talk about the source of the investigative problem, who frames the investigative questions, how they conduct the designing stage of investigations, how they conduct the actual investigation, how data is collected during investigations and how conclusions are drawn and how they made observations among other things pertaining to the instrument.

Analysis

Quantitative data were analyzed using SPSS for Windows version 16.0 whilst categorical analysis (Stake, 1995) was used to analyze qualitative data. To analyze Likert items, a taxonomy of learner perceptions about classroom inquiry was created based on the existing literature consistent with the current National and International Science Education Reform documents (Campbell, et al., 2010). All 20 statements were scored on bipolar Likert-scale ranging from; (1) never occurred (2) seldom, (3) sometimes, (4) often, to (5) almost always. In scoring, each item response was allocated 1, 2, 3, 4 or 5 from almost never to almost always respectively. Scoring was done in reverse for those statements representing non-inquiry or closed inquiry laboratory. Examples of such items are: B1, and C2. A high score

(maximum = 100) is taken to mean that the nature of instruction in that laboratory is generally perceived as open-inquiry and a low score (minimum = 20) means laboratory work is verificationistic or closed inquiry. Reverse scoring was done for the following items: A1, A2, A3, A4, B2, B3, B4, C1, C3, C4, D1, D2, D3, D4, E1, E2, E3 and E4. The scores could then be used to place instructional practice along a continuum ranging from verificationistic/expository to open-ended inquiry. However, in this case, the scores were used to perform inferential statistics, i.e., standard multiple regression analysis. Multiple regression was used to explain how much of the variance the dependent variable (Total Score, which represents sum of construct based out of possible 20) could be explained by the independent variables (five inquiry facets). Multiple regression analysis also gave an indication of the relative contribution of each independent variable in determining levels of learner perceptions. All this was done to test criterion and construct validity of the instrument with regards to the South African classroom context.

Results

Regression analysis can be applied to establish both criterion and construct validity (Miller, Meier, Muehlenkamp, & Weatherly, 2009). For criterion validity, an independent variable can be used as a predictor variable and a dependent variable, the criterion variable. The correlation coefficients between them are called validity coefficients. In this case, each category (subscale) representing the practice of scientific inquiry is an independent variable and the total score of the instrument is the dependent variable which aims at determining the extent to which learners experience inquiry during science lessons. Using multiple regression, correlation coefficients were calculated which are equivalent to the validity coefficients. For construct validity, the measured correlation between the intended independent variable (construct) and the proxy independent variable (indicator, sign) was determined such as learners' responses to the LPCI instrument. Here correlation is assumed between for example getting a high score on the LPCI instrument and practicing open-ended inquiry. Standard multiple regression was used to perform the two afore-mentioned validity processes. Results are presented in the order of research questions.

Tables 1 and 2 provide data to address the first research question; how well do the five principles of scientific inquiry predict learners' perceptions of classroom inquiry?

Table 1 shows that the five variables correlate substantially (that is, r is between 0.605 and 0.794) with the dependent variable – Facet Total. One of the variables, Facet 4 'collecting data' has a correlation of 0.794 with Facet Total which is a bit too high. Facet 1 'framing research questions' and facet 2 'designing investigations' have a bivariate correlation of less than 0.3 with facet 5 which is 0.199 and 0.139 respectively. Tabachnick and Fidell (2001) suggest that a variable should have correlation between 0.3 and 0.7 for it to be significant. Tabachnick and Fidell (2001, p. 84) suggest that one has to "think carefully before including two variables with a bivariate correlation of, say, 0.7 or more in the same analysis". Because only one variable 'collecting data' had a high correlation, greater than 0.7, after thinking carefully it could not be omitted since there was no other variable to form a composite variable with it. The other two variables had correlation below 0.3 but because they showed at least some relationship with the dependent variable, facet total score, they were retained when running Multiple Regression Normality plot analysis.

Table 1. LPCI Likert-Score Correlations ($N = 90$)

		Facet1	Facet 2	Facet 3	Facet 4	Facet 5	Facet Total Score
Facet1	Pearson Correlation	1	.416**	.190**	.437**	.199**	.685**
	Sig. (1-tailed)	.	.000	.037	.000	.030	.000
Facet 2	Pearson Correlation	.416**	1	.336**	.336**	.139*	.632**
	Sig. (1-tailed)	.000	.	.001	.001	.096	.000
Facet 3	Pearson Correlation	.190**	.336**	1	.383**	.316**	.639**
	Sig. (1-tailed)	.037	.001	.	.000	.001	.000
Facet 4	Pearson Correlation	.437**	.336**	.383**	1	.399**	.794**
	Sig. (1-tailed)	.000	.001	.000	.	.001	.000
Facet 5	Pearson Correlation	.199**	.139*	.316**	.399**	1	.605**
	Sig. (1-tailed)	.030	.096	.001	.000	.	.000
Facet Total	Pearson Correlation	.685**	.632**	.639**	.794**	.605**	1
	Sig. (1-tailed)	.000	.000	.000	.000	.000	.

** . Correlation is significant at the 0.05 level (1-tailed).

* . Correlation is significant at the 0.01 level (1-tailed).

Facet Total = sum of inquiry facet (construct) out of a possible 20

Facet = average of the facet (construct) with the highest value being 5.

Collinearity diagnostics was performed on the five variables since they had significant correlation with the dependent variable as part of the multiple regression procedure. This was done to pick up problems with multicollinearity that may not have been evident in the correlation matrix and to also check if we had done the right decision of not dropping the variables which pretended to be outliers earlier. The results are presented in Table 2.

Table 2. Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients		Collinearity Statistics		
		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	2.315	.000		.000	1.000		
	Facet1	1.000	.000	.319	1.255	.000	.724	1.381
	Facet 2	1.000	.000	.250	1.001	.000	.749	1.336
	Facet 3	1.000	.000	.270	1.096	.000	.771	1.297
	Facet 4	1.000	.000	.356	1.327	.000	.650	1.538
	Facet 5	1.000	.000	.280	1.162	.000	.807	1.239

a. Dependent Variable: Facet Total Score

Two values are given in table 2 namely tolerance and VIF [Variance inflation factor]. Table 2 shows that the tolerance value for each independent variable is between 0.650 and 0.724. Pallant (2005) suggests that if the value is very small (less than 0.10), it indicates that multiple correlation with other variables is high, suggesting the possibility of multicollinearity. Tolerance is an indicator of how much of the variability of the specified independent variables in the model is not explained by the other independent variables in the model and is calculated using the formula $1-R^2$ for each variable. In this case, the multicollinearity assumption was not violated. VIF is just the inverse of the tolerance value (1 divided by Tolerance). VIF values above 10 would be a concern here, indicating multicollinearity. VIF values are between 1.036 and 1.142 which are well below the cut-off of 10. This further supports the fact that there is the multicollinearity assumption was not violated.

The Model Summary box (Table 3) help us address the *second research* question, how much variance in learners' perceptions of classroom inquiry can be explained by scores on these five principles of scientific inquiry?

Table 3. *Model Summary*^b

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000 ^a	1.000	1.000	.000

a. Predictors: (Constant), Facet 5, Facet 2, Facet 3, Facet 1, Facet 4

a. Dependent Variable: Total Score

Looking in the Model Summary box (Table 3), the given value under the heading R Square is 1.000. This tells how much of the variance in the dependent variable (Total Score) is explained by the model (including the five variables). Expressed as a percentage, it means the model (which includes the five variables) explains 100 per cent of the variance in Total Score. However, a sample of 90 can be considered not very big so the R square value in the sample tends to be rather an optimistic overestimation of the true value in the population hence the Adjusted R square statistics 'corrects' the value to a better estimate of the true population value. Because the standard Error of the Estimate is 0.000, in this case, this remains 100 per cent. This is highly a respectable result when comparing to some of the results that are reported in literature. Finally, from multiple regression analysis conducted, statistical significance of the result was assessed by checking from the output tabled ANOVA. This tested the null hypothesis that multiple R in the population equals 0. The model reaches statistical significance (Sig .000, $p < .0005$) meaning result is statistically significant.

To determine which of the variables included in the analysis contributed to the prediction of the dependent variable (research question 3), Beta values under Standardized Coefficients (Table 2) gave this information. 'Standardized' means that values for each of the different variables were converted to the same scale for comparison. Facet 4 'Collecting data' had the largest beta value, 0.356. This meant that this variable makes the strongest unique contribution to explaining the dependent variable, inquiry facet total score when the variance explained by all other variables in the analysis is controlled for. The beta value for facet 1 'Asking questions/framing research questions' was slightly lower (0.319) indicating that it made a less contribution compared to facet 4. The remaining facets had less contribution to the dependent variable in the following order; Facet 5 'Drawing conclusions' (0.280), facet 3 'conducting investigations' (0.270) and facet 2 'designing investigations' (0.250). All five variables made a significant unique contribution to the prediction of the dependent variable as suggested by Pallant (2005) because their Sig. values (see, Table 2) are all less than 0.05. Actually they have the same Sig. value which is 0.

Assumptions like outliers, normality, linearity, homoscedasticity and independence of residuals were checked using two different ways. These are: inspecting the Normal Probability Plot of the regression standardized residuals and the residual scatterplot. These were requested as part of the analysis. Figure 1 gives a scatterplot of the standardized residual analysis. From Figure 1, the residuals are roughly rectangularly distributed, with most scores concentrated in the centre (along the 0 point). There is no clear or systematic pattern to the residuals (e.g. curvilinear, or higher on one side than the other) showing that there are no deviations from a centralized rectangle suggesting that there is no violation of the assumptions.

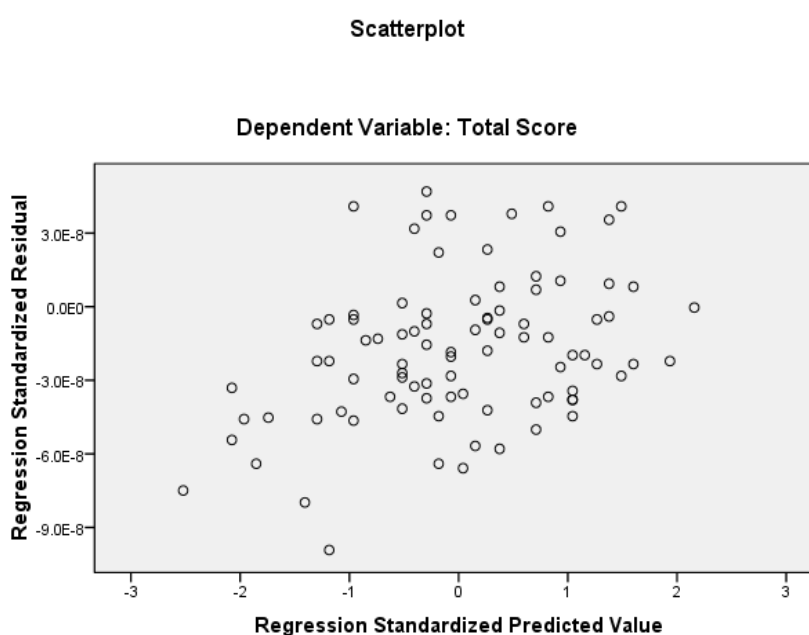


Figure 1. Scatterplot of the standardized residual analysis

Interview results

Four interviews were conducted with four University experts (one interview with each) in the field of laboratory work focusing on content validation of the LPCI instrument. In the case of determining learners' levels of perceptions of classroom inquiry, content validity addressed the question of whether the instrument's items actually capture (are relevant to) the constitutive constructs, latitude of openness given to learners during investigations (as discussed under the theoretical framework). With the experts having the depth and know-how of the prospective study in which the instrument is to be used, they all agreed that the instrument's items captured the constitutive constructs of learner perceptions in determining the extent of inquiry they experience in science classrooms. All four gave the instrument a thumbs up. Regarding content validity, the instrument can be said to be valid. Two focus groups were held with ten learners, five in each group. Overall both groups had this to say on the instrument:

“...the LPCI is just one page, it is short enough. The language is so simple. It asks about what we do during practical investigations and how we do it. The statements are also short and most important of all are very clear”.

Taking the above responses into account, the instrument superficially appears to measure what it is suppose to measure. The instrument can therefore be said to be valid at face value.

Discussion

Pertinent review of literature suggests that several researchers have utilized standard multiple regression as a method to validate instruments (see, e.g. Heppner, Kivlighan, & Wampold, 1992; Meyer, Miller, Metzger, & Borkovec, 2002; Sullivan & Karlsson, 1999). Most of these instrument validation studies are conducted in Clinical Psychology although there are a few in Education on student ratings of instruction and student achievement (e.g. Cohen, 1981). It is noteworthy to mention at this point that the goal of research is to explain phenomena. One way of explaining how certain events predict an outcome is by measuring how predictive

variables are when they are combined together and it is one major reason why Multiple Regression was used for validating the LPCI.

Evidence of relevant concern relating to criterion and construct validity of the LPCI instrument is provided by the findings of the study. Results from multiple regression analysis show that five variables correlate substantially and because correlation is substantial, no variable was dropped before running the collinearity diagnostics. Collinearity diagnostics was performed on the five categories of the instrument since they had significant correlation with the dependent variable as part of the multiple regression procedure. No problems were found with multicollinearity. Assumptions like outliers, normality, linearity, homoscedasticity and independence of residuals were checked and no violations to the assumptions were found. A Cronbach alpha value of 0.80 was obtained. The actual questionnaire responses used in the production of the instrument produced a Cronbach alpha of 0.85 (Campbell, et al., 2010) for the whole instrument. Since criterion validity is about prediction rather than explanation and is concerned with non-casual or mathematical dependence, the multiple regression analysis results provided evidence relating to criterion validity of the instrument.

Construct validity is the degree to which an instrument measures the trait or theoretical construct that it is intended to measure (Miller, Meier, et al., 2009). Construct validity therefore examines the fit between the conceptual definitions and operational definitions of variables. Other schools of thought (see, e.g. Angoff, 1988; Cronbach & Quirk, 1976; Li, 2003) argue that construct validity cannot be expressed in a single coefficient; hence there is no mathematical index of construct validity. Rather the nature of construct validity is qualitative. Like what other researchers (Angoff, 1988; Cronbach & Quirk, 1976; Li, 2003) suggest, we examined the fit between the conceptual definitions and operational definitions of variables qualitatively. Interview data became crucial here. Since the instrument is adopted, exploratory factor analysis had been conducted and found to be substantially significant. Therefore construct validation took into account indicator analysis. These findings are consistent with previous work by Campbell, et al., (2010) with 130 secondary science students in the Western state, USA.

In explaining how much variance in learners' perceptions of classroom inquiry could be explained by scores on these five principles of scientific inquiry, the model (which includes the five variables) explained 100 per cent of the variance in Total Score. The model also reached statistical significance (Sig .000, meaning $p < .0005$) meaning result is statistically significant. Beta values under Standardized Coefficients gave information on the best predictor of learners' perceptions of classroom inquiry. Facet 4 'Collecting data' had the largest beta value, 0.356 and this meant that this variable makes the strongest unique contribution to explaining the dependent variable, inquiry facet total score when the variance explained by all other variables in the analysis is controlled for. These results show that both criterion and construct validity were tested for in the instrument through use of multiple regression as done in other studies (see, e.g. Arozullah, et al., 2007; Osborne, 2000). Clearly, the use of multiple regression as a methodological technique became useful in finding out how to predict phenomena related to learner perceptions in classroom inquiry.

Content validity refers to the extent to which an instrument measures a representative sample of subject-matter content and behavioural content from the syllabus which is being measured (Cohen, Manion, & Morrison, 2000). That capture was cognized in terms of the statistical balance and representation of the product and process dimensions of inquiry. In other words, content validity was essentially about checking the operationalization against the relevant

content domain for the two constitutive constructs. Before the instrument was given to the learners for completion, it was given to four University Professors for content validation. The four university experts gave credence to this effect. *Face validity* defined as the extent to which casual, subjective inspection of an instrument's items indicates that they cover the content that the instrument is claimed to measure (Gall, Gall, & Borg, 2003). It is about looking at the operationalization and seeing whether "on its face" the instrument seems like a good translation of the construct (McGartland & Kimberly, 2005; Miller, Uleryk, & Dorai, 2009). In this study, the construct being levels of perception of classroom inquiry. From learner interviewing, the instrument was given a thump up regarding this validity aspect.

Conclusion

Instrument validation implies accumulation of many different types of evidence that indicate to what degree an instrument measures what it is intended to measure. Golafshani (2003) defines validity as the extent to which the instrument measures what it purports to measure. The LPCI instrument was designed to measure learners' perceptions of classroom inquiry for an example, and the question raised is did it manage to do so? The instrument superficially appears to measure what it is suppose to measure basing on inferential statistics results and interview data basing on the findings. The instrument actually measured perceptions and not assumptions or beliefs? In other words, the LPCI instrument allows us to hit 'the bull's eye' of our research object in the intended study. These preliminary results provide evidence of relevant satisfaction that relates mainly to the instrument having passed the test in terms of criterion, construct, content and face validity. No inquiry facet or item shall be dropped basing on the performed inferential statistics from the South African context. The implication is that the instrument can be adopted for future use in measuring the extent of learner perceptions of classroom inquiry in larger populations.

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Appendix A

This questionnaire wants to find out what you think about what you experience during science lessons. Indicate how often you think each of the activities listed happens during your science lessons by ticking (✓) in the appropriate box.

Item	Almost never	Seldom	Some-times	Often	Almost always
A Learners ask questions/framing research questions: in the science classroom					
A1 I formulate questions which can be answered by investigations					
A2 My research questions are used to determine the direction and focus of the lab					
A3 Framing my own research questions are important					
A4 Time is devoted to refining my questions so that they can be answered by investigations					
B Designing investigations: in the science classroom					
B1 I am given step-by-step instructions before they conduct investigations					
B2 I design their own procedures for investigations					
B3 We engage in the critical assessment of the procedures that we employ when we conduct investigations					
B4 We justify the appropriateness of the procedures that are employed when we conduct investigations					
C Conducting investigations: in the science classroom					
C1 I conduct my own procedures of an investigation					
C2 The investigation is conducted by the teacher in front of the class					
C3 I actively participate in investigations as they are conducted					
C4 I have a role as investigations are conducted					
D Collecting data: in the science classroom					
D1 I determine which data to collect					
D2 I take detailed notes during each investigation along with other data I collect					
D3 I understand why the data I am collecting is important					
D4 I decide when data should be collected in an investigation					
E Drawing conclusions: in the science classroom					
E1 I develop my own conclusions for investigations					
E2 I consider a variety of ways of interpreting evidence when making conclusions					
E3 I connect conclusions to scientific knowledge					
E4 I justify my conclusions					