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# TEACHERS' INSTRUCTIONAL STRATEGIES AND THEIR IMPACT ON LEARNER PERFORMANCE IN GRADE 9 MATHEMATICS: FINDINGS FROM TIMSS 2015 IN SOUTH AFRICA

## ABSTRACT

*Teachers use a variety of instructional strategies when they teach various mathematical topics and concepts. Some of these strategies have been found to positively affect the performance of learners while others do not. This study analysed the teacher questionnaire data from the Trends in International Mathematics and Science Studies (TIMSS) 2015 study in which the teachers indicated the instructional strategies that they used in the mathematics classrooms. The five instructional strategies that were determined from the groupings of the questions were teacher-teacher interaction, teacher-learner interaction, teacher explanation of the content, problem solving with direct teacher guidance and problem solving without direct teacher guidance. The results indicate that the two instructional strategies of problem solving with direct teacher guidance and teacher-teacher interaction were found to be significantly associated with learner performance across the four content domains of algebra, numbers, geometry and data and chance.*

**Keywords:** *Instructional strategies; learner performance; factor analysis; linear regression; TIMSS.*

## 1. INTRODUCTION

One of the main aims of teaching and the activities undertaken in the classroom by teachers is to provide learners with the fundamental content knowledge required to enhance what they already know (Lu, 2019; Tebabal & Kahssay, 2011). To ensure that learners understand what is taught by the teacher, different instructional strategies are applied in the classroom. These instructional strategies are usually selected according to the content to be presented.

Education has evolved from traditional teacher-centred methods to methods that are more interactive and learner-centred (Lu, 2019); however, to this day the effectiveness of the student-centred approach for learner performance is questioned by many (Zhao *et al.,* 2017). Most research conducted to date has investigated the effect that teaching methods have on learners' academic achievement (Adunola, 2011; Ganyaupfu, 2013), with studies showing in cases where the majority of learners perform poorly in the same class setting, it is inevitably linked to the utilisation of ineffective instructional strategies (Ganyaupfu, 2013). Since learners' academic achievement is often used as an indicator of the quality of teaching provided, this study explored the effect of instructional strategies on the performance of learners.

## 2. PROBLEM STATEMENT

The purpose of this study was to examine academic achievement in the various Grade 9 mathematics content domains in the 2015 Trends in International Mathematics and Science Studies (TIMSS) in relation to the instructional strategies and practices employed by teachers. The intention was to determine whether the instructional strategies and practices that the teachers identified in the TIMSS 2015 differed depending on the content domain taught. With the move from the traditional teacher centred methods to those more focused on the learner it stands to reason that a one size fits approach to instructional practices is not possible as was shown by Ganyaupfu in 2013 (Ganyaupfu, 2013). Thus as an extension to the work done by Ganyaupfu, the article attempts to identify the various forms of instructional practices and determine if these practices vary dependent on the mathematics content domain being taught.

## 3. INSTRUCTIONAL STRATEGIES AND PRACTICES

Numerous instructional strategies and practices have been identified as characteristic of effective teaching or have been recognised as characterising effective teachers. Such instructional strategies and practices have become the focus of initial teacher education and continuing professional development training programmes. Even though the use of identified instructional strategies and practices does not guarantee an effective teacher (Hoge, 2016), they are used by teachers in mathematics classrooms. Instructional strategies and practices should only be regarded as characteristic of quality teaching if there is evidence (Eriksson, Helenius & Ryve, 2018) that they generally have a positive effect on student achievement. Emphasising the importance of instructional strategies, Gregory and Chapman (2013) argue that teachers need a wide variety and vast amount of these strategies in order to teach information in a variety of ways. They indicate that this is necessary in order to address the uniqueness of the learners in the classroom. A wide variety of instructional strategies and practices not only addresses the uniqueness of the learners, but also enables the teachers to develop meaning and understanding for the benefit of the learners (Levine, 1994). The California Department of Education (CDE, 2015) places greater responsibility on the role of the teacher in relation to instructional strategies. The CDE (2015) indicates that since a wide range of instructional strategies is available to teachers, effective teachers are those who look for a fit between the material to be taught and strategies for teaching that material.

Instructional strategies and practices are everything that teachers use to aid learners in their learning process and are the means to bring about effective teaching and learning (Amos, Folasayo & Oluwatoyin, 2015). Obara and Okoh (2005) explain instructional strategies as everything teachers utilise to interactively enhance, motivate and facilitate teaching and learning for the achievement of set objectives. Instructional strategies are part of classroom practices (Arends, Winnaar & Mosimege, 2017) that are intended to improve learning and

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student achievement. Nichols (2015) regards instructional strategies as a subset and one of the components of instructional practices. She defines instructional strategies as techniques that teachers use throughout instruction to support comprehension of the concepts being taught. Nichols (2015) also explains that instructional practices include programmes, strategies and other factors related to instruction as identified by school personnel. Gregory and Chapman (2013) do not define instructional strategies and practices or explain what they are; however, they allude to their importance by indicating that teachers are constantly seeking innovative ways to teach important information. When the information has been taught, it is followed by assessment of what the learners have learnt. The effectiveness of the strategies employed by teachers has a bearing on how the learners perform. The relationship between instructional strategies and practices is discussed later in this article. However, it is important to highlight that the activities that teachers engage in have a bearing on the extent of the knowledge gained by the learners in classroom interaction.

Whether teachers use a list of identified instructional strategies and practices or use those that they identify as their own that are not on the list of identified or documented strategies by other scholars, teachers tend to use a variety of such strategies and practices in their daily classroom activities. These strategies are employed in the classroom for the purpose of improving the learning experiences and performance of the learners in various assessment activities. The main question (which is also the focus of this study) is the extent to which the use of such strategies and practices translate into increased and improved learner performance in mathematics. Stated differently, this question explores whether the choice of strategies by teachers makes any significant contribution to the performance of learners in the assessment activities they are subjected to.

Arguing for the use of instructional strategies, Carr and Bertrando (2012) state that we must imagine a set of research- or evidence-based instructional strategies and tools that all teachers could use to help struggling students learn vocabulary, discourse, content and skills in science classes or comprehend complex text in any academic content area. In order to illustrate this view, Carr and Bertrando suggest that we should

> envision two students with learning disabilities who are learning English in two secondary schools. The student at one school struggles to learn and adapt each hour to the different ways the different teachers teach, as well as the different content. The student in the other school focuses only on the different content, because one set of strategies is known and habitually used by all teachers (2012:24).

Carr and Bertrando (2012) further suggest that the student struggles as a result of being exposed to different teaching strategies; whereas the other student, who is exposed to different teachers who use the same or standard strategies, is able to focus on and master the content.

Other effects of instructional strategies are that they ensure the effective achievement of stated instructional objectives (Nafees *et al.,* 2012) and increase student achievement (Dean *et al.,* 2012). Lipton (1995: 183–184) recommends the following general instructional strategies, which are characteristic of elementary and secondary communicative-based language classrooms:

- Keep the use of English to a minimum, with most instructions, directions and explanations given in the target language.
- Use real objects, gestures, pictures and other visuals to convey meaning.

- Focus on language that is concerned with functional situations and authentic utterances.
- Do not always insist on complete sentences but mirror natural speech patterns.
- Adopt a conversational approach that replicates "real" situations that are likely to occur.
- Teach vocabulary in context, including all kinds of idiomatic phrases.
- Use paired activities and small-group learning.
- Use technology.
- Use a variety of print and non-print materials.
- Strive to develop cultural awareness using authentic cultural realia as a springboard for communication in the language.
- Emphasise acceptable communication, rather than near-native pronunciation.
- Ensure a match between the learner and the language in terms of relevance and learning styles.

Even though the instructional strategies recommended by Lipton (1995) are more specific to language classrooms, they are equally important in other classrooms. The use of technology is not only a necessity given Fourth Industrial Revolution developments, but it is an essential component to help learners in a variety of classrooms, including mathematics classrooms.

Killian (2016) argues that evidence-based teaching strategies are regarded as those strategies that are likely to have the largest impact on student results. Among the strategies that he identifies are questioning to check for understanding, summarising new learning in a graphical way, plenty of practise, providing the students with feedback and getting students to work together in productive ways.

Harris, Phillips and Penuel (2012) investigated the following instructional strategies to help students develop their ideas and questions in a science classroom:

- Discuss students' ideas written in journals and posted in public charts.
- Discuss students' questions about the lesson.
- Revise students' ideas about the lesson.
- Discuss students' research questions and plans for investigations.
- Reflect with students on what they have learnt and how they came to know.

The three main instructional strategies that Harris *et al*. (2012) identified and explored are discuss, revise and reflect. They report that the three teachers who participated in their study differed in the way they applied the three instructional strategies.

The different mathematics sections and topics in the Senior Phase and Further Education and Training Phase require different teaching strategies to be employed by the teachers as they make an effort to assist the learners to have a better understanding of mathematical concepts and content. Some of these strategies are based on what the teachers were trained on when they were in pre-service education, whereas some strategies have been gained in teacher professional development programmes.

This article reports on an analysis of instructional strategies and practices that teachers indicated they used to help learners with various mathematical concepts. This study analysed

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the data from the TIMSS 2015 in South Africa to determine the strategies that teachers identified in the teaching of mathematics in Grade 9.

## 4. INSTRUCTIONAL STRATEGIES AND LEARNER PERFORMANCE

Even though TIMSS studies have been undertaken since 1995, not all of them have specifically considered the relationship between classroom practices and learner performance (Mullis *et al.,* 2012). Mullis *et al*. (2012) indicate that the only TIMSS studies that considered this relationship were the 2003 and 2007 studies. It is for this reason that all internationally available evidence on the effect of teaching practice is mostly drawn from the data of these two years. The 2015 TIMSS study (from which the data for this study were drawn) therefore contributes to research that explores this relationship.

Studies on the effect of instructional strategies and learner or student performance in mathematics and other subjects have provided differing results. Eze (2011) found that instructional strategies that included differentiated instruction, flexible grouping and teaching for higher-order thinking skills had the most significant relationship with student achievement in mathematics, whereas administrative supervision did not have a significant relationship with student achievement.

Onweh and Akpan (2014) investigated the effect of the following strategies on students' performance in electrical installations in technical colleges: discussion, lecture and demonstration. They found that the demonstration strategy had the most significant effect on student academic performance in electrical installations.

Jepketer (2017) differentiates between student-centred instructional strategies, teacher-centred instructional strategies and assessment strategies, and examined the impact of each of these strategies on student performance. Following her research, Jepketer (2017) developed a model in which she indicates that when teaching strategies are strengthened through targeted in-service training, student performance is influenced.

## 5. THEORETICAL FRAMEWORK

The theoretical framework used in this study is the Theory of Didactical Situations (TDS) developed by Brousseau (1997). Sriraman and English (2010) describe the TDS as a three-way schema in which the complexity of the interaction between the teacher, the student and the content is studied. The Theory of Didactical Situations seeks to offer a model, inspired by the mathematical theory of games, to investigate, in a scientific way, the problems related to the teaching of mathematics and the means to enhance it (Radford, 2008; Yuliani, 2016). Mangiante-Orsola, Perrin-Glorian and Stromskag (2018) contend that TDS represents a didactical situation in which the focus is on the teacher with the perspective of understanding how the students learn and how the teacher helps them learn some mathematical content. In this way, the teacher acts as a facilitator in a learning environment. In TDS (Selman & Tapan-Broutin, 2018), the emphasis is to create a class environment in which students act like scientists and/or researchers in which they discover and produce. The environment for these discoveries is facilitated and enhanced by the teacher. TDS also provides an opportunity to isolate moments of instruction, action, formulation, validation and institutionalisation in the mathematics teaching and learning process (Wisdom, 2014). This study followed the TDS framework to explore the instructional strategies that were identified by the teachers in order to assist the learners to solve mathematics problems. The study specifically looked at the role of the teacher within TDS to determine how they created an appropriate environment and facilitated problem solving for the learners.

## 6. RESEARCH APPROACH AND METHOD

This section provides the details pertaining to the TIMSS 2015 sample, the variables used and derived from the teacher contextual questionnaire and the analytical techniques employed to answer the research questions.

### 6.1 The TIMSS 2015 data and sample

The data that served this analysis were obtained from the TIMSS 2015 database. TIMSS is a trend study administered every four years and conducted by the International Association for the Evaluation of Educational Achievement (IEA). The main purpose of the TIMSS study is to measure the overall health of a country's education system. This is measured by administering contextual questionnaires to school principals and mathematics and science teachers, as well as learners. In addition to the contextual data, a mathematics and science assessment is administered to learners. The analysis for this research included data extracted from the teacher mathematics questionnaires, as well as learner scores for each of the content domains. The 2015 TIMSS in South Africa was conducted by the Human Sciences Research Council (HSRC). The HSRC has conducted all the TIMSS studies that the country has participated in since 1995, when the first round of these studies was undertaken.

The TIMSS sample was selected using a two-stage stratified sampling procedure where a representative sample of schools was selected in the first stage and a random intact Grade 9 class was randomly selected within each sampled school in the second stage. The South African sample included approximately 12 000 students, 300 principals, 300 mathematics teachers and 300 science teachers.

In responding to the research question, which focused on instructional strategies teachers use when teaching the four mathematical content domains, questions from the teacher contextual data were extracted. Since the sample of teachers is not representative of the population of teachers in South Africa, the teacher data were merged with the student data and the analyses were interpreted in relation to the students taught by mathematics teachers.

### 6.2 Measures

The following sections provide details pertaining to the outcome (dependent) variables and the independent variables/measures.

#### 6.2.1 Outcome/dependent variables

The TIMSS curriculum and assessment framework for Grade 9 study is organised around the mathematics content domains of numbers, algebra, geometry, data and chance, and the percentage share of items in the TIMSS test was 30%, 30%, 20% and 20%, respectively. In addition to estimates of student scores, the IEA also provides scores per student for each of the four content domains. In this analysis, each of these content domain scores served as a dependent variable to determine whether the instructional strategies teachers employed differed depending on the content domain taught.

The TIMSS follows a matrix sampling approach to divide mathematics items into 14 different booklets. Each learner must complete only one of the 14 booklets, which means that a learner is not expected to complete all items that exist in the TIMSS study. In order to calculate an overall score, the IEA uses Item Response Theory and multiple imputations to calculate five possible score estimates called plausible values. These plausible values are standardised to a mean of 500 and standard deviation of 100 to allow for cross-country comparisons.

### 6.2.2 Teacher instructional strategies identified in the study (independent variables)

Twenty-four variables were found to relate to instructional strategies and the principal component analysis (PCA) was used to reduce these variables into scales that measure the same constructs (See Tables 1 and 2). The PCA is a dimension reduction tool that focuses on the contribution that each variable makes to explain the variance in a particular construct. It creates various linear combinations of the variables and eventually selects a combination where the maximum amount of variance is explained.

**Table 1:** Total variance explained

| Component | Initial eigenvalues | | | Extraction sums of squared loadings | | | Rotation sums of squared loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | % of variance | Cumulative % | Total | % of variance | Cumulative % | Total | % of variance | Cumulative % |
| Teacher interaction | 6.415 | 26.7 | 26.7 | 6.4 | 26.7 | 26.7 | 4.4 | 18.4 | 18.4 |
| Teacher-learner interaction | 3.072 | 12.8 | 39.5 | 3.1 | 12.8 | 39.5 | 3.2 | 13.4 | 31.8 |
| Problem solving without direct teacher guidance | 1.826 | 7.6 | 47.1 | 1.8 | 7.6 | 47.1 | 2.8 | 11.6 | 43.4 |
| Teacher explanation of content | 1.608 | 6.7 | 53.8 | 1.6 | 6.7 | 53.8 | 2.2 | 9.3 | 52.7 |
| Problem solving with teacher guidance | 1.253 | 5.2 | 59.1 | 1.3 | 5.2 | 59.1 | 1.5 | 6.3 | 59.1 |

Extraction Method: PCA.

**Table 2:** Rotated component matrix[a]

| | Component | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Discussed how to teach a particular topic with other teachers | 0.729 | | | | |
| Collaborated in planning and preparing instructional material | 0.826 | | | | |
| Shared their teaching experiences | 0.775 | | | | |
| Visited another class | 0.686 | | | | |
| Worked together to try out new ideas | 0.826 | | | | |
| Worked as a group to implement the curriculum | 0.803 | | | | |

| | Component | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Worked with teachers from other grades to ensure continuity of learning | 0.728 | | | | |
| Related lessons to the students' daily lives | | 0.417 | | | |
| Asked students to explain their answers | | 0.699 | | | |
| Asked students to complete challenging exercises that go beyond instruction | | 0.517 | | | |
| Encouraged classroom discussion among students | | 0.668 | | | |
| Linked content to prior knowledge | | 0.579 | | | |
| Let students decide their own problem-solving procedures | | 0.706 | | | |
| Encouraged learners to express their ideas in class | | 0.753 | | | |
| Listened to the teachers' explanation of new mathematics content | | | | 0.860 | |
| How to solve problems | | | | 0.877 | |
| Memorised rules, procedures and facts | | | | 0.725 | |
| Worked on problems individually with the teacher's guidance | | | | | 0.653 |
| Worked on problems as a whole class | | | | | 0.751 |
| Worked on problems while the teacher is occupied with other tasks | | | 0.726 | | |
| Worked on problems for which there is no direct method of solution | | | 0.718 | | |
| Took a written test or quiz | | | 0.695 | | |
| Worked in mixed-ability groups | | | 0.488 | | |
| Worked in same-ability groups | | | 0.708 | | |

Extraction Method: PCA. Rotation Method: Varimax with Kaiser normalisation.

a. Rotation converged in five iterations.

For this analysis, the results of the PCA provided five broad constructs that explained aspects of instructional practices. The variances explained by each of the constructs are provided in Table 3, with teacher-teacher interactions explaining the most variance (26.7%) and the factor related to problem solving with direct teacher guidance explaining the least variance (5.2%). Table 3 indicates the percentage of the variance as well as the cumulative percentage of the total variance for each of the constructs.

**Table 3:** Total variance explained by each of the constructs of instructional practices

| Construct | Initial eigenvalues | | | Extraction sums of squared loadings | | | Rotation sums of squared loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | % of variance | Cumulative % | Total | % of variance | Cumulative % | Total | % of variance | Cumulative % |
| Teacher-teacher interaction | 6,415 | 26,7 | 26,7 | 6,4 | 26,7 | 26,7 | 4,4 | 18,4 | 18,4 |
| Teacher-learner interaction | 3,072 | 12,8 | 39,5 | 3,1 | 12,8 | 39,5 | 3,2 | 13,4 | 31,8 |

| Construct | Initial eigenvalues | | | Extraction sums of squared loadings | | | Rotation sums of squared loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | % of variance | Cumulative % | Total | % of variance | Cumulative % | Total | % of variance | Cumulative % |
| Problem solving without direct teacher guidance | 1,826 | 7,6 | 47,1 | 1,8 | 7,6 | 47,1 | 2,8 | 11,6 | 43,4 |
| Teacher explanation of content | 1,608 | 6,7 | 53,8 | 1,6 | 6,7 | 53,8 | 2,2 | 9,3 | 52,7 |
| Problem solving with direct teacher guidance | 1,253 | 5,2 | 59,1 | 1,3 | 5,2 | 59,1 | 1,5 | 6,3 | 59,1 |

Details pertaining to each of the five constructs are as follows:

i. **Teacher-teacher interaction**, with a reliability score of 0.896, was the first component and consisted of seven variables that explained 26.7% of the variance in the sample. In this construct, teachers were asked questions that related to instructional strategies and practices that involved interaction between teachers. The questions covered the following aspects: how often they discussed how to teach a particular topic with other teachers, collaboration with other teachers in planning and preparing instructional material, sharing their teaching experiences with other teachers, visiting another teacher's class, working together with other teachers to try out new ideas, working as a group with other teachers to implement the curriculum and working with teachers from other grades to ensure continuity of learning.

ii. **Teacher-learner interaction**, with a reliability score of 0.802, consisted of seven statements and explained 12.8% of the variance. In this construct, the teachers were asked questions that related to the instructional strategies and practices between teachers and students. The questions asked in this construct were as follows: when teaching the TIMSS class, teachers were asked how often they related lessons to the students' daily lives, whether they asked the students to explain their answers, whether they asked the students to complete challenging exercises that go beyond instruction, whether they encouraged classroom discussion among students, whether they linked content to prior knowledge, whether they let the students decide their own problem-solving procedures and whether they encouraged learners to express their ideas in class.

iii. **Problem solving with direct teacher guidance:** The reliability score for this component was 0.645 and explained 7.6% of the variance. The component included two statements covering the following: how often teachers asked learners to work on problems individually with the teacher's guidance and how often they asked learners to work on problems as a whole class.

iv. **Teacher explanation of the content** included three variables. The variables included the following questions: how often the teachers asked the students to listen to the teachers' explanation of new mathematics content and how to solve problems and memorise rules, procedures and facts. The reliability score for this component was 0.791 and explained 6.7% of the variance.

v. **Problem solving without direct teacher guidance**, with a reliability score of 0.740, consisted of seven statements and explained 5.2% of the variance in the sample. The statements included in this component related to problem-solving ability without direct guidance from the teacher. The teachers were asked how often they asked learners to work on problems while the teacher is occupied with other tasks, whether they asked learners to work on problems for which there is no direct method or solution, whether they asked the learners to take a written test or quiz, whether they asked the learners to work in mixed-ability groups and whether they asked the learners to work in same-ability groups.

### 6.2.3 Data analyses

Multiple regressions were used to analyse the data. Multiple regressions model the relationship between a dependent variable and two or more independent variables. The aim of each of the regression models is to ascertain associations between the five components of teacher instructional strategies and student performance in each of the four content domains. As previously mentioned, five dependent variables were included in the analyses and for this reason five multiple regressions were run using an analysis package created by the IEA called International Database (IDB) Analyzer. The IDB Analyzer is a statistical analysis package specifically designed to analyse data from IEA large-scale projects and takes studies' methodological intricacies into account. The IDB Analyzer creates syntax files (or programme files) of a particular selected analysis and, using the Statistical Package for the Social Sciences (SPSS), runs the files and creates output results.

## 7. RESULTS

This section first provides the results of the descriptive analysis, followed by the multiple regression assumption tests as well as the regression analysis.

### 7.1 Descriptive analysis

Learners obtained the highest mean score in algebra (394), followed by numbers (368.87), geometry (364.19) and lastly data and chance with a mean score of 357.02 (see Table 4).

The dependent variables ranged from a minimum of 1 to a maximum of 4, with higher values indicative of positive responses on the scale. All the dependent variables, with the exception of "Problem solving without direct teacher guidance", scored on average closer to the maximum value of the scale. Teachers were less likely to use classroom practices where learners were expected to work out mathematics questions without the teachers' direct involvement.

**Table 4:** Descriptive analyses

| Variable | Sample size | Mean | Standard deviation |
|---|---|---|---|
| Algebra | 12 074 | 394,01 | 87,01 |
| Data and chance | 12 074 | 357,02 | 95,89 |
| Geometry | 12 074 | 364,19 | 88,34 |
| Numbers | 12 074 | 368,87 | 91,61 |
| Problem solving without direct teacher guidance | 12 074 | 2,42 | 0,66 |
| Problem solving with direct teacher guidance | 12 074 | 3,27 | 0,63 |
| Teacher explanation of the content | 12 074 | 3,25 | 0,69 |
| Teacher-teacher interaction | 12 074 | 2,78 | 0,68 |

| Variable | Sample size | Mean | Standard deviation |
|---|---|---|---|
| Teacher-learner interaction | 12 074 | 3,24 | 0,53 |

## 7.2 Multiple regression

The regression results for each of the four content domain models are provided in Table 5.

The first model explained 7% of the variance in algebra achievement scores, with only two of the five instructional strategies being associated with achievement in algebra. Learners who were taught by teachers who spent more time explaining content obtained 16 points more on average (β = 16, $p < 0.05$) than learners taught by teachers who performed this task less often.

A significant but negative association is observed between achievement and problem solving without direct teacher guidance. Learners who were taught by teachers who spent more time allowing learners to solve problems without direct teacher guidance obtained on average 38 points fewer (β = -38, $p <0.01$) than their counterparts.

The second model explained 9% of the variance in learner performance in the numbers content domain. As with algebra, only two of the five independent variables were significant. A score difference of 20 points (β =20, $p < 0.05$) on average was observed between learners taught by teachers who spent more time explaining the content and those who did not.

A negative relationship exists between achievement in the numbers domain and learners taught by teachers who expected learners to solve problems without teacher guidance (β = -43, $p < 0.01$).

The third model explained 8% of the variance in achievement scores in relation to the geometry content domain. In relation to the geometry content domain, a score difference of 18 points (β = 18.4, $p < 0.01$) was observed with learners taught by teachers who spent more time explaining the content obtaining higher scores than their counterparts.

A significant but negative association exists between the average score in the geometry content domain and “Problem solving without direct teacher guidance” strategy (β = -40, $p < 0.01$).

The fourth model focused on the association between the data and chance content domain and the instructional strategies, of which two were found to be significant. The model explains 9% of the variance in achievement. A 21-point difference in score on average is observed between learners taught by teachers who focused more attention on ensuring that the content was adequately explained (β = 21, $p < 0.05$). As with the other models, a significant but negative relationship exists between achievement in data and chance and the strategy where a teacher expects learners to solve problems without direct assistance from the teacher (β = 43.9, $p < 0.01$).

**Table 5:** Multiple linear regression results

| | Algebra (Model 1) | | Numbers (Model 2) | | Geometry (Model 3) | | Data and chance (Model 4) | |
|---|---|---|---|---|---|---|---|---|
| | **B** | **β (s.e)** | **B** | **β (s.e)** | **β** | **β (s.e)** | **β** | **β (s.e)** |
| Constant | 395 | 28 | 375.8 | 29.9 | 368.3 | 29.2 | 370.4 | 30.9 |
| Problem solving without direct teacher guidance | -38** | 7 | -43** | 7.5 | -40** | 7.1 | -43.9** | 7.8 |
| Problem solving with direct teacher guidance | 1 | 8.5 | 0.3 | 8.8 | 1.5 | 8.5 | 1.3 | 9.2 |
| Teacher explanation of the content | 16* | 6.3 | 20.3* | 6.5 | 18.4* | 6.3 | 21.1* | 6.7 |
| Teacher-teacher interaction | 9 | 8.5 | 10.2 | 8.8 | 9.1 | 8.4 | 9.9 | 9.4 |
| Teacher-learner interaction | 3 | 8.5 | 0.7 | 9 | 0.8 | 8.7 | -2.2 | 9.7 |

** p-value < 0.01, * p-value < 0.05

## 8. DISCUSSION AND CONCLUSION

The main aim of the study was to identify the various instructional strategies available in the TIMSS 2015 data and to model all these with each of the mathematics content areas available in the Grade 9 curriculum. This was done to determine the relationship between the instructional strategies and student performance in each of the mathematics content domains. The study revealed the following five instructional strategies: teacher-teacher interaction, teacher-learner interaction, teacher explanation of the content, problem solving without direct teacher guidance and problem solving with direct teacher guidance. The results showed that two of the five instructional strategies were significantly associated with student performance, regardless of the mathematics content domain modelled. The first of these were problem solving without direct teacher guidance and the second was teacher explanation of the content; however, the direction of association of these two constructs differed considerably.

Students who were taught by teachers who explained the content to them obtained scores ranging between 10 and 21 points more on average than students taught by teachers who did not explain the content. Explanation of content is therefore necessary and critical, especially for mathematical content that learners are unfamiliar with. Ganyaupfu (2013) concurs with this result because he found in his research that teacher-learner interaction is the most effective teaching method (Ganyaupfu, 2013).

Problem solving is an important activity in enhancing the understanding of mathematical concepts by learners. The role that teachers play in problem solving is therefore very important for learners. Two constructs (instructional practices) related to problem solving in this study, namely (i) problem solving with direct teacher guidance and (ii) problem solving without direct teacher guidance. Even though not significant, the results for the construct of problem solving with direct teacher guidance showed a positive association with academic achievement; meaning that learners taught by teachers who provided guidance when problem solving obtained higher scores than their counterparts. The role that teachers play during the period when learners are involved in problem solving is vital (Alsawaie, 2003) and can only become more significant if they do it thoroughly and intentionally, with a specific purpose. In order to help students to perform better in problem solving, teachers are required to make a shift from the traditional role of lecturer-demonstrator to a role that demands new skills in planning and facilitating students' work (Simon, 1986). Further emphasising the role of teachers, Schoenfeld (1992) states that teachers must perceive the implications of students' different approaches and must decide when to intervene and what suggestions will help the student to be successful in problem solving. The guidance of the teacher is therefore crucial in problem solving and will certainly contribute, not only to the ability to solve problems successfully, but will also positively affect learners' performance.

The opposite was, however, true when examining the problem solving without direct teacher guidance construct. Problem solving without teacher assistance was negatively associated with academic achievement, regardless of the content domain being analysed. Learners taught by teachers who employed this instructional practice scored an average of between 38 and 44 points fewer than learners taught by teachers who did not employ this strategy. Reif (1995) found that content learning is vital when teaching mathematics; however, it is not sufficient when a learner is faced with solving problems in a textbook. He found that even though learners knew the facts and principles, they were unable to apply that knowledge when problem solving. What learners are doing is memorising solutions of previously completed problems and examples, without understanding how to apply existing knowledge in problem solving.

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## 10. DECLARATION

The authors declare that all calculations and interpretations of statistics are correct.

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