Primary School Teachers’ Pedagogical Content Knowledge of stem-leaf plots

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Abstract

This study interrogated Primary School Teachers’ Pedagogical Content Knowledge (PCK) of stem-and-leaf plots (stem-leaf plots). The topic under study was introduced in grade 5 of the Zambian primary school mathematics curriculum, as well as in Primary Teachers’ Colleges of Education. It had never existed in the Zambian school curriculum from early education to Primary teacher diploma education levels. Bruner’s constructivist theoretical perspective guided the study. Data was collected from 37 primary school teachers through a written questionnaire task on stem-leaf plots. Further data was gathered from a Grade 5 teacher through lesson observations and for triangulation purposes, post-lesson interviews were conducted. The teacher was purposefully selected to teach his class on the topic in question. Video- and audio-recording techniques were employed respectively to capture reality. Overall results indicated that the respondents had scant ideas about stem-leaf plots with regard to both content and pedagogy. During the teaching process, the teacher missed opportunities in the application of enactive, iconic and symbolic modes. The teacher displayed gaps in using learners’ experiences and prior knowledge. He could not collect real data or use manipulatives to enhance active learning. Concepts were not extrapolated beyond the data given, thus a clear implication of stem-leaf plots was not drawn. In view of these findings, the authors recommended the need for further studies to address the link between stem-leaf plots and numeracy, and the amplification role of stem-leaf plots in data organisation, representation and analysis. They also proposed studies involving attitudes of teachers toward statistics (stem-leaf plots) to be conducted. It is also necessary for teacher educators to include strategies to examine how student teachers handle real data in classrooms including stem-leaf plots as tools for organising and analysing data.

Key words: Mode, statistics, stem-leaf plots, primary school teacher, PCK
Introduction
Investigation of primary school teachers’ Pedagogical Content Knowledge of stem-leaf plots was necessitated by the Zambian government’s curriculum reform programme to introduce statistics from grade 2 up to tertiary education. Stem-leaf plots were only introduced in grade 5 and third (final) year of primary teacher education. The initiative was justified by the importance of statistics in all the sectors of life. Experience in teacher education also showed that despite its usefulness, statistics was unpopular to many teachers. In view of this, authors sought to describe the extent to which primary school teachers were prepared to teach stem-leaf plots to children at grade 5 level.

Research problem
Despite the importance of statistics, research worldwide showed inadequacies in teachers’ knowledge for teaching statistics in general (Kashoka, 2019; Leavy, 2010; Chick & Pierce, 2008; Burgess, 2007; Wild & Pfannkuch, 1999) and stem-leaf in particular (Williams, Sorto, Pierce, Lesser & Murphy, 2015). Besides, there seems to be few studies on stem-leaf plots. Given this scenario, the researchers sought to understand teachers’ knowledge for teaching stem-leaf plots in primary schools. Little was known about such knowledge and competencies, hence the need for this research.

Research objectives
The objectives of the study were to:
• Assess teacher’s content knowledge of stem-leaf plots.
• Determine teachers’ pedagogical knowledge of stem-leaf plots

Theoretical framework
Bruner’s (1966) constructivist theoretical perspective was used to analyse the data. Constructivism is a learner-centred theoretical position that knowledge is a compilation of human-made invention. It is a learning theory that concerns the process of how humans come to know new knowledge based on their past experiences from the things around them. Bruner, through his theory of discovery learning, postulated that human beings have three ways (modes) of knowing; through physical actions (enactively), through imagery (iconically) and through language (symbolically). The theory accounted for predispositions, structure, sequence, and reinforcement in the preparation of instruction. He argued that,

“To instruct someone…is not a matter of getting him to commit results to mind. Rather, it is to teach him to participate in the process that makes possible the establishment of knowledge. We teach a subject not to produce little living libraries on that subject, but rather to get a student to think mathematically for himself…to take part in the process of knowledge-getting. Knowing is a process, not a product” (Bruner, 1966, p. 72)
Bruner highlights key points about constructivism as a learner-centred approach such as participation whilst acknowledging the need for independent mathematical thinking and that knowing is a process (means) and not the product (end). In unison with Bruner’s proposition, Cobb (1988, p. 89) argued that “the goal of instruction is or should be to help students build [mental] structures that are more complex, powerful, and abstract than those that they possess when instruction commences”. Bruner’s theoretical framework, ‘Towards a theory of instruction’ emphasises “the teaching context, student prior knowledge, and active interaction between the learner and the content to be learned” (Major, 2012, p. 140).

The authors, therefore, argued that meaningful learning of stem-leaf plots for primary school children could be best achieved through the use of learners’ experiences and prior knowledge, their active involvement in data collection and careful use of multiple representations. These map a structure that enables learners to ‘visualise’ the learning process and minimise reliance on textbook knowledge. Moreover, the authors posited the need for instruction in the symbolic mode to emphasise interpretation, implication, and dealing with learner misconceptions and errors. In order to achieve this, the study also drew ideas from Shulman’s (1987) and Ball, Thames & Phelps’ (2008) conceptions of PCK as well as Curcio’s (1987) taxonomy of graph comprehension (Estrella, Olfos & Mena-Lorca, 2015; Jacobbe, 2007; Sorto, 2004).

Significance of the study
Realising that stem-leaf plots introduced a new term in Zambia’s primary school mathematics curriculum, it was envisaged that the study would bring to the fore an understanding of teachers’ subject matter knowledge and their competences to teach stem-leaf plots. The authors also thought that findings would contribute to research in Mathematics Education on the knowledge requirements for teaching stem-plots at primary school level, thereby contributing to promotion of STEM Education.

Conceptual note: Nature and application of stem-leaf plots
A stem and leaf diagram as a way of organising data was devised in the 1960s by John Tukey, an American mathematician and statistician (Scheiber, 2009). It is also referred to as a stem and leaf graph, stem-and-leaf plot, stem-leaf plot or simply stem plot (Williams, et al, 2015; Gattuso, 2008; Sorto, 2004; Pereira-Mendoza & Dunkels, 1989). However, this paper addresses it as a stem-leaf plot. The technique is most appropriately used to represent and compare two sets of ungrouped quantitative data; both discrete and continuous data. A stem-leaf plot is the only graphical representation that also displays all the original data values (Scheiber, 2009; MOE, 2001). The method gives an opportunity to decipher the shape, location and variability of the distribution, more especially for fairly large data sets. The key concepts such as symmetry, skewness, mode, mean, median, range, outliers, clusters and gaps can be deciphered from the stem-leaf plot just as with a line plot and histogram.
Working with stem-leaf plots consolidates development of many other mathematical concepts such as place value, estimations (rounding) and truncations (Gattuso, 2008; Dunkels, 1991; Pereira-Mendoza & Dunkels, 1989). In a stem-leaf plot, stem-values need to be evenly spaced and no stem-value should be skipped. Display of data on a stem-leaf plot, employs the rule-of-the-thumb; the last (right-most) digit in each data item is the leaf while the remaining digit(s) form a stem. Construction of stem-leaf plots may conveniently start with ordering numerical data. The order so established makes it possible to visualise the range of values within which stems must lie. Eventually data values are plotted by making a vertical list of stems. Each number is assigned to the graph by pairing the units digits, or leaf with the correct stem value. It is necessary to create a key and title for the graph as well as the sample size. In case of numerically larger data items, it is good practice to indicate a stem multiplier to allow the reader to interpret the magnitude of the data values.

There are essentially two variations and extensions of stem-leaf plots; split stems and back-to-back (multiple or double) stem-leaf plots. The former is used when some categories have many data points. Thus spreading the data points becomes necessary, by splitting the stems into a smaller number of equally-sized units. On the other hand, back-to-back stem plots are useful when comparing two data sets. In such instances construction of a double stem-leaf plot becomes a necessity.

**Study design and methodology**

Data was collected from 37 primary school teachers randomly picked from five (5) peri-urban schools of the same district. A written task was administered, followed by lesson observations and post-lesson interviews with one of the teachers (grade 5 teacher). The teacher held a primary teachers’ diploma with a 3-year teaching experience. He was purposefully selected as he happened to teach stem-leaf plots at the time of data collection. According to the revised curriculum stem-leaf plots by then were only introduced in grade 5 and in primary teachers’ colleges of education. The task, which was one of the 14 questions in the main study (Kashoka, 2019) was adapted from Sorto’s, (2004) test administered to the American teachers for grade 4 and 6 levels. The test items were reliable with reliability index between $\alpha = 0.70$ and $\alpha = 0.90$. Observation method was employed to help describe the teacher’s knowledge of teaching stem-leaf plots. The method is known for eliminating subjective bias (Kothari & Garg, 2014) and, “the information obtained under this method relates to what is currently happening; it is not complicated by either the past behaviour or future intentions” (ibid, 2014, p.91). Direct observations are a more natural way of collecting data (Burgess,
2009; Burgess, 2007; Sidhu, 2006). Direct personal interviews are also a useful means of exploring someone else’s ideas or thinking about something (Edwards, 1996). In fact interviews are said to be the best way of collecting data because, “through the respondent’s incidental comments, facial and bodily expressions, tone of voice, gestures, reactions, feelings, attitudes, evasions and non-cooperation, an interviewer can acquire information that would not be conveyed by any other way” (Sidhu, 2006, p.146). Talking to the participant (grade 5 teacher) also helped us establish his beliefs about and attitudes towards stem-leaf plots (statistics) better. Audio-recording of interviews after the lessons helped in capturing the necessary data.

Findings and discussion

Research question 1: Teacher’s content knowledge of stem-leaf plots.

The written question on stem-leaf plots was administered two weeks before the lesson observations and interviews were conducted. It was adapted from Sorto, (2004) to measure the three levels of graph comprehension (Friel, Cursio & Bright, 2001). That is, part (a) tested teachers’ knowledge of extracting information from the given data, part (b) to find relationships while part (c) was to help them think beyond the given data. Figure 1 depicts the task teachers responded to:

<table>
<thead>
<tr>
<th>Minutes to Travel to School</th>
<th>0</th>
<th>3 3 5 7 8 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 2 3 5 6 6 8 9</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0 1 3 3 3 5 5 8 8</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0 5</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

(a) How many pupils are in the class?
(b) How many pupils took less than 15 minutes to travel to school?
(c) From the stem-leaf plot, find the modal and median time taken.

Figure 1: Task for respondents
The teachers displayed shaky knowledge of stem-leaf plots. Part (a) required them to state the number of pupils who were involved in the walk to school. In part (b) the teachers were supposed to state the number of pupils who took less than 15 minutes to travel to school and state modal and median time taken in (c). They were expected to justify their responses. Findings revealed that 78.3% (29 of 37) obtained zeros, 13.5% (5 of 37) got 1 mark, while 2.7% (1 of 37) scored 3 marks out of 4 and 5.4% (2 of 37) scored 4 out of 4. It was further learnt that no respondent 0% (0 of 37) obtained 2 marks out of 4. Figure 2 shows the responses obtained.

![Bar chart](image)

**Figure 2: Task scores**

From the findings depicted in Figure 2, it was very clear that the teachers involved in the study had scant ideas about stem-leaf plots. These results confirmed the teachers’ initial views about their familiarity with certain statistical concepts. Prior to the task, respondents were asked to select the statistical concepts that were easy for them to teach. Responses indicated that of all the concepts provided, stem-leaf plots were the most unpopular and received only 15% of the choices (Kashoka, 2019, Figure 4.3).
The following are sample scripts (by score cohorts) to show the actual performance by the respondents in this study:

**Cohort A: 0 of 4**

(a) How many pupils are in the class? 
(b) How many pupils took less than 15 minutes to travel to school? 
(c) From the stem-leaf plot, find the modal and median time taken. Explain in each case.

**Cohort B: 1 of 4**

(a) How many pupils are in the class? 
(b) How many pupils took less than 15 minutes to travel to school? 
(c) From the stem-leaf plot, find the modal and median time taken. Explain in each case.

**Cohort D: 3 of 4**

(a) How many pupils are in the class? 
(b) How many pupils took less than 15 minutes to travel to school? 
(c) From the stem-leaf plot, find the modal and median time taken. Explain in each case.

**Cohort E: 4 of 4**

(a) How many pupils are in the class? 
(b) How many pupils took less than 15 minutes to travel to school? 
(c) From the stem-leaf plot, find the modal and median time taken. Explain in each case.

**Figure 3. Teachers’ responses from the item**

Findings revealed that out of the 37 teachers only 7 (18.9%) managed to read and think within the stem-leaf plot (a) while 3 (8.1%) of them related the data points given (b). Only 4 (10.8%) teachers thought beyond the stem-leaf by finding the modal time taken (c) while 2 (5.4%) found the median (cii). A total of 17 (45.9%) teachers left blank spaces in (b) while 14 respondents (38%) did not even attempt to answer the question on stem-leaf plots. Figure 4 summarises this information.
In the above figure, all those respondents who left blank spaces or completely left the questions unanswered were counted among wrong responses.

Data clearly shows that the majority of the respondents had marked challenges in interpreting the display. It has been shown in Figure 3 that some teachers even obtained a zero score. Figure 4 indicates that performance declined from part (a) to (c) with (cii) being the worst. This scenario demonstrates teachers’ lack of content knowledge on the three levels of graph comprehension; to think within the graph, establish relationships and extrapolate the statistical ideas (Curcio, et al, 2001). The three levels of graph comprehension are a progression from mere counting of data points to logical reasoning.

**Research question 2: Teacher’s Pedagogical knowledge of stem-leaf plots.**

After the written question, the grade 5 teacher (T5) was purposefully selected to teach his class on stem-leaf plots. The example he gave to his learners was about a farmer who picked pineapples from Monday to Thursday for the Saturday market (Figure 5).

*Teacher: So, let us see how they collected different workers* (how the different workers collected pineapples). (Continues writing the example involving Kelvin, Henry and Bupe.)
Figure 5: Example on stem-leaf plots

(After finishing writing, the teacher takes the class through the example).

Teacher: Okay, these are the collected data, according to the farmer; uyu umuntu uwakwete ifamu (This person who had a farm). Now acitile (he did) employ three, Kelvin, Henry and Bupe. On four days they collect these pineapples, isn’t it? Now we want to use stem-leaf plot. How are we going to use stem-leaf plot? Okay, let us see, let us first collect data

Teacher: (Writing) The data collected be written in ascending order.

Teacher: Okay, when they are saying data collected must be written in ascending order, what does it mean?

Learners: (Quiet)

Teacher: When they say put the data into ascending, what does that mean?

Learners: (Quiet)

Teacher: This means that you are going to put the numbers from the smallest to the biggest! (Chorusing)

Teacher: Yesss...like this (Writes) 13, 14, 17, 22, 22, 28, 30, 31

Teacher: Are we there?
From the data collected, learners were expected to plot the number of pineapples picked by the three workers on a stem-leaf display.

The authors described the teacher’s competences under salient emerging sub-themes within the constructivist perspective. These were analysed relative to Bruner’s three modes of intellectual thinking; enactive, iconic and symbolic as follows:

**Use of learners’ experiences and prior knowledge**
Although the example the teacher used on data collected by the farmer related to learners’ experiences, he missed the opportunity of exploring learners’ experiences on farming or the pineapples in the question. The following was the classroom scenario:

*Teacher: (Writing subject, ‘MATHEMATICS’ on the chalkboard). Ok, we will start with mathematics. Someone to remember what we did last time? I want someone to remember what we did last time.*

*Learner 1: Pie graph*

*Teacher: Ooh! Very good, pie graph? What do you mean by pie graph?*

*Learner 1: (Quiet)*

*Teacher: What do you mean by pie graph? (Extends the question to the rest of the class). Okay, today we are looking at statistics ai (not so)?*

*Learners: Yes*

*Teacher: Yes we are looking at statistics (writing the topic ‘STATISTICS’ on the chalkboard). Now, statistics is under collecting and presenting data aini (not so)?*

*Learners: Yes*

*Teacher: There is a formula which we need to use to collect data. Our friend mentioned pie graph aini (not so)?*

*Learners: Yes*

*Teacher: Pie graph is one way we collect data, show and write it into a graph aini (not so)?*

*Learners: Yes*

*Teacher: What is the other one? The other one? They are two.*

*Learner 2: Bar graph (inaudible)*

*Teacher: Ok, someone?*

*Learner 3: Stem and leaf*

*Teacher: Very good! Stem and leaf. There is a stem (pronounced as stim) and leaf and also a pie bar graph, aini (not so)?
As can be noted from the above excerpt, the teacher tried to make a recap of the work from previous grades, unfortunately he and his class started talking about pie graphs (a topic for grade 7 level). Bruner’s (1966) concept of spiral curriculum and effective sequencing requires that teachers revisit basic ideas over and over, building upon them and elaborating to the level of full understanding and mastery.

Data collection and use of manipulatives
There was neither evidence of data collection activity in class nor physical manipulation of concrete materials by the class during the entire lesson. The teacher depended solely on textbook data which according to Nair & Pool, (1991, p.202) might contain ‘dead information’ and lack value in children’s learning.

Bruner (1966) emphasised the need for active learning through some hands-on activities (enactive mode) to promote independent research using readily available materials. Therefore, the researchers felt engaging learners in data collection could have helped them to understand the concept of stem-leaf better. The next competence relates to Bruner’s iconic mode which emphasises the use of visual aids.

Use of multiple representations

The teacher struggled to demonstrate the iconic mode of the stem-leaf plot. Although during the interview he confidently stated that he had taught the lesson before, it appeared he was learning the concept of stem-leaf plot right on the job. There was no clear picture made to map the implication of this graphical representation. Stem-leaf plots connect well with the concept of place value in which the stem could refer to the 10s (tens) while the leaves to the 1s (units).

Figure 6 below shows the stem-leaf plot generated from the data given in the example in Figure 5. Its interpretation makes use of the concept of place value.

<table>
<thead>
<tr>
<th>stem</th>
<th>leaf</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3, 4, 7</td>
</tr>
<tr>
<td>2</td>
<td>2, 2, 8</td>
</tr>
<tr>
<td>3</td>
<td>0, 1, 0</td>
</tr>
<tr>
<td>4</td>
<td>0, 1</td>
</tr>
</tbody>
</table>

Interpreted as 39, i.e. 3 tens and 9 ones

Figure 6: Stem-leaf plot
Teacher clarified the answer to the class, “On the stem we are going to write 1 then on the other side, on the leaf there we are going to write the number which are left (remaining), ok!” This explanation did not map a clear picture of place value thus promoting instrumental rather than relational understanding (Skemp, 1977). Being explicit in explaining stem-leaf as 10s and 1s could have helped learners develop a deeper, and proportional relationship. For instance, when one learner was asked to explain where 4 (leaf under stem 1) had come from, assumptions made were that,

“It is like we add 10 plus 4, then it gave us 14. Then we moved 1 and remained with 4”. For 30s the same learner stated that, “we write 3 to the stem, then we write 0, 1, 9, 9 to the leaf side”.

The child did not associate what was left or the leaf side with the ones. The class however completed the stem-leaf plot as shown in Figure 6.

Stem-leaf plots should not have commas as in Figure 6 above but a key should be included to guide readers (Figure 7). This is necessary especially when dealing with fractions, large numbers or with back-to-back stem-leaf plots. A title is also required.

**Number of fruits collected**

<table>
<thead>
<tr>
<th>Stem</th>
<th>Leaf</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3 4 7</td>
</tr>
<tr>
<td>2</td>
<td>2 2 8</td>
</tr>
<tr>
<td>3</td>
<td>0 1 9 9</td>
</tr>
<tr>
<td>4</td>
<td>0 1</td>
</tr>
</tbody>
</table>

**Key**  
4 0 = 40

**Figure 7: Ideal plot**

Having stressed the importance of visual aids, the authors now stress the need for the knowledge of data interpretation which enables the teacher to analyse learners’ misconceptions, errors and mistakes. These constitute Bruner’s symbolic mode.
Interpretation of data

Data presentation in itself is not adequate until meaning is extracted from it. Interpretation enables the reader to make sense of the information given. Statistics at this level does not need sophisticated interpretation; procedures and tests but the teacher needs to help learners ‘view’ data to conjecture patterns and possibilities (Pereira-Mendoza, 1990). In other words this extrapolation of ideas helps learners to think beyond the information given (Chick & Pierce’s, 2008; Curcio, 1987; Bruner, 1973; Bruner, 1966). Pereira-Mendoza suggests “placing the stages of data collection, representation and interpretation and prediction within a meaningful environment” p.261. From this standpoint, the authors argue that stem-plots should be taught meaningfully to the learners. This requires collection of ‘real data’ (Pereira-Mendoza, 1990, p. 262), summarising, displaying and making sense of the data.

Little was done by the class on interpreting stem-leaf plot as the teacher pointed out during interviews as given in the following transcript:

Researcher: Do you face challenges in teaching? Let us be specific, like in case of that lesson (referring to stem-leaf plot), what challenges did you face in teaching? Perhaps you can even comment on the challenges that learners faced.

Teacher: “Yeah, statistics, yes, because of the numbers which are involving there (which were involved). Some learners are not well...good, you know... it is difficult for them to understand. Yeah, and to interpret that information for example the stem-leaf and also the bar graph”.

Authors felt the teacher could have encouraged interpretation by asking learners to describe the completed stem-leaf plot in their own words or ask probing questions to help learners think beyond what was on the plot. For instance, the highest number of fruits, least number or common number of fruits and to pass a general comment on the overall pattern (distribution) or questions like how many fruits were collected altogether? How many pupils collected less than a given quantity? Prompts of this kind could have ignited learners’ interpretational skills to help them think about the implication of the data. That is, what the data tells us (Gattuso, 2008). This is where children now think about the differences in the distributions of data (Franklin & Mewborn, 2008, p.12).

Error identification and remediation

The teacher was not very helpful to slow learners and seemed to have ignored to comment on ‘inappropriate’ answers. For instance, the following learner needed guidance which the teacher could not provide despite seeing the work (Figure 8).
The learner (Figure 8) even went up to 40s and yet the maximum number in the task was 38, it appeared like the learner followed the answer from the example (Figure 6). She also included a zero stem which had no place in the task. The teacher did not seem to have noticed this, otherwise he could have taken this opportunity to explain to the class how the zero stem could come in and how it could be handled since the example did not capture this part. It was observed that in many situations the teacher could not spot errors in learners’ work and almost everyone did not get the required solution sought but he indicated ‘V. good’ (Figure 9).
When writing the numbers in ascending order, this learner repeated the first six numbers which are 10, 12, 14, 16, 18 and 18. It is noticeable that the learner could not make a thorough arrangement of all the numbers in ascending order as evidenced by the misplacement of 30, 22 and 32. Besides, the learner omitted the numbers, 21, 21, 22, 25, 26, 27 and 28 while an extra 30 was included in the list.

**Ideal solution**

In an ideal situation, the class could have presented their solution as follows:

(a) Ordering (Ascending)

10, 12, 14, 16, 18, 18, 19, 20, 21, 21, 22, 22, 23, 24, 25, 25, 26, 26, 27, 28, 30, 30, 32, 33, 34, 35, 38.

(b) Stem-leaf plot

<table>
<thead>
<tr>
<th>Scores obtained out of 40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stem</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
</tbody>
</table>

| Key | 3 8 = 38 |

These results conform to Williams, *et al* (2015, p.3) findings that, “teachers’ lack of confidence to teach certain concepts was related to their lack of familiarity with the newer ideas in their statistics curriculum, such as stem and leaf graphs…” Largely, this explains the challenges the teacher encountered in teaching as shown in table 1:

**Table 1: Thematic analysis of teacher’s competences**

<table>
<thead>
<tr>
<th>Modes</th>
<th>Themes</th>
<th>Teacher’s competences by theme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enactive</td>
<td>Experience and prior knowledge</td>
<td>No evidence of using learners’ prior knowledge and experiences</td>
</tr>
<tr>
<td></td>
<td>Data collection and manipulatives</td>
<td>No evidence of data collection or manipulation of physical objects.</td>
</tr>
<tr>
<td>Iconic</td>
<td>Multiple representations</td>
<td>No other visual displays used apart from chalkboard illustrations</td>
</tr>
<tr>
<td>Symbolic</td>
<td>Interpretation</td>
<td>Could not properly map implication of stem-leaf plots but focused on plotting.</td>
</tr>
<tr>
<td></td>
<td>Error identification and remediation</td>
<td>Shaky scaffold due to inability to recognize and engage with learner errors.</td>
</tr>
</tbody>
</table>
Bruner (1966) emphasised the role of the teacher in facilitating and guiding, which was later re-defined as ‘scaffolding’ (Bruner, Wood & Ross, 1976). For teachers to guide learners properly, they need to have sound pedagogical knowledge of stem-leaf plots. However, findings from this research revealed gaps in teacher’s knowledge of the practice of teaching stem-leaf plots in line with the Bruner model.

Shulman (1987, p.8; Ball, et al., 2008) described PCK as ‘a special amalgam of content and pedagogy that is uniquely the province of the teachers, their own special form of professional understanding’. It is therefore arguable that teachers understand what to teach (concept of stem-leaf plots) and how to teach it.

In their quest to elaborate Shulman’s categories of knowledge bases; Subject Matter Knowledge (SMK) and Pedagogical Content Knowledge (PCK), Ball et al., (2008) suggested the domains of SMK to include common content knowledge (CCK), mathematical horizon content knowledge (HCK) and specialised content knowledge (SCK). They viewed pedagogical content knowledge as comprising knowledge of content and students (KCS), knowledge of content and teaching (KCT), and knowledge of content and curriculum (KCC). This entails that for the teacher to guide learners with their errors and misconceptions, he/she needs to know the content bearing in mind what learners are capable of doing, the appropriate methods and strategies as well as the curriculum requirements of the topic for the given grade level.

**Conclusion and recommendations**

Overall, the teachers under study show-cased very weak subject matter knowledge of stem-leaf plots especially at interpretational level. Interpretation helps learners to think, within, between and beyond the information given (Chick & Pierce’s, 2008; Curcio, 1987; Bruner, 1973; Bruner, 1966) and sometimes behind the data (Estrella, 2015; Curcio, 1987). While Bruner’s theory promotes activity-based instruction, the teacher in the lesson illustrated concepts on the chalkboard (iconic) but missed opportunities in the enactive and symbolic modes. In order to teach stem-leaf plots well, teachers need a firm foundation of both content knowledge and pedagogical knowledge.

Authors therefore, recommended that schools intensify in-house staff training programmes such as Teacher Group Meetings (TGMs) in topic-specific areas of statistics such as stem-leaf plots. Future researches need to show the link between stem-leaf plots and numeracy in primary schools. Tertiary institutions should emphasise error analysis and remediation as a separate topic in mathematics education. Teaching in the 21st century also demands that teachers know how to analyse data by stem-leaf plots using ICT. Above all, researchers, teachers and teacher educators could also use Bruner’s framework for improved instructional pedagogy.
References


Jacobbe, T. (2007). Elementary school teachers’ understanding of essential topics in statistics and the influence of assessment instruments and a reform curriculum upon their understanding, Dissertation; Doctor of Philosophy in curriculum and Instruction: Clemson University