Exploring the Performance of Zimbabwean Children on Piagetian Formal Operations Tests

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Research Article

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ABSTRACT

The case study was designed to examine the performance of 110 form 3 and 4 pupils who participated in a modified Piagetian Formal Operations Test (PFOT). Modification of the PFOT was necessary for more object familiarity on the part of the Zimbabwean learner. The PFOT was designed to find out how local learners would fare on selected cognitive tasks meant to test formal operations thinking. The mean score in the PFOT results was calculated at $\bar{x} = 39\%$ with a standard deviation of 12.19. The study revealed that 40 (9%) of the participants obtained a score below the mean whilst 59 (1%) obtained a score above the mean. Test data collected reflected that 82% of local learners rarely reached formal operational criterion in cognitive performance. A number of respondents still operated within the concrete operations of the Piagetian developmental stages of cognition. A number of variables influencing cognition of learners were unveiled, for example, domestic violence, politics, cultural practices and noisy neighbourhoods. The study reminded parents that they are their children’s first and foremost teachers and they should work in collaboration with the schools in order to enhance performance on cognitive tasks among learners.

Keywords: cognitive performance, Piagetian, formal-operations, tests.

BACKGROUND

By the beginning of the 1990s, a number of educationists noted a serious gap in research on cognitive performance of learners at the formal operations stage of Piaget's (1932) cognitive development theory. Many researchers were rather limited to his early stages such as the sensory-motor, pre-operational and concrete operational stages (Mwamwenda, 2004). Research findings were also generalized globally yet there are many differences in socioeconomic status, family definitions, beliefs, attitudes, values, parental guidance skills and many other factors that differ and may affect cognition.

According to Valencia et al. (1985) in Valencia (1997), some studies have examined the relative contributions of family status variables where a number of tests were used. These ranged from the Handerson’s Environmental Learning Process Scale (HELPS) to predict cognitive performance and the General Cognitive Index (GCI) of MacCarthy Scales of Children’s Abilities (MASCA). These instruments, whose items are sometimes evaluated as culture-fair, were designed for the Western world. They were also approved globally as instruments to facilitate the prediction of cognitive performance. Zimbabwe, with its various ethnic groups was also included. A number of studies in Africa and abroad have been carried out involving cognitive performance of learners. In most of the studies, Piaget's (1932) cognitive developmental theory was the integral notion (Mwamwenda, 2004). These studies have also confirmed that Piaget’s cognitive developmental theory can be validated cross-culturally.

Piaget’s comprehensive theory has been proven useful and insightful that it remains the major force in the cognitive area of developmental psychology today (Huffman et al., 2000). This is evidenced by the many research studies supporting or disputing the theory, in both qualitative and quantitative formats (Siegel, 2009). But what does Jean Piaget say about cognitive development? How does the human intellect develop from the basic abilities present at birth to impressive skills exhibited in middle childhood or adolescence? It has, however, been noted that despite the potential relevance of Piagetian theory to the school curriculum, few studies have addressed the theoretical relationship of Piaget’s theory to how children perform at school (Mwamwenda and Mwamwenda, 1989 in Sigelman and Rider, 2011). A great deal of researches has focused on the concrete operations stage. It has been noted that there is hardly any serious attention being paid to other developmental stages whose significance cannot be supplanted by the concrete operations stage. This contention is confirmed by Ohuche and Otaala (1981) and Dasen (1981) both cited in Mwamwenda (1990:105). In a review of cross-cultural studies of Piagetian concepts it is proposed that:
“...future agenda should focus on the neglected and untapped areas of Piaget's theory. Particular attention ought to be given to the stage of formal operations since it serves as a predictor of academic performance at the secondary school and tertiary levels of education” (Mwamwenda, 1990: 105).

It is for this reason that this study is mainly focusing on learners at secondary school level in Zimbabwe whose majority are presumed to be operating at, plus or minus the formal operations stage of cognitive development. Durojaiye (1990) has also tried to review Piaget's cognitive developmental theory, but still not many studies have made reference to the formal operations stage in Africa, particularly in Zimbabwe. With this brief background, it is the intention of this study to examine the cognitive performance of local secondary school children.

THEORETICAL FRAMEWORK

This study is tethered on the cognitive works of Jean Piaget. Though many psychologists might have disputed the works of Piaget, his theory's criticisms are generally not considered serious enough to offset his enormous contributions. Some consider him the most influential epistemologist-philosopher of all times because his theory is validated cross-culturally. The theory has also been a great stimulation for many researches on human cognition. The information processing model, cited by O'Neill (2011) for instance, has been influenced highly by Piaget's theory.

Unlike behaviourists, who view people as merely reacting to environmental stimuli, he saw people as actors on their environment (Huffman et al., 2000). He believes people purposefully form cognitive representations of, and seeks to manipulate the world or their surroundings. Piaget was a schema theorist because he believed that the nature of our schemata change with development. It becomes more abstract as we grow. He saw cognitive development as a series of qualitatively different stages that are tied to changes in schemata. In 1963, Jean Piaget hypothesised that children’s cognitive processes develop in an orderly sequence of stages. Some children, however, may be more advanced than others at particular ages (Piaget and Inhelder, in Gallagher and Reid, 2002). He identified four stages of cognitive development namely; the sensori-motor, pre-operational, concrete operational and formal operations represented in figure1 below (Huffman et al., 2000; Santrock, 2003; Mwamwenda, 2004; Fieldman, 2008; Kosslyn and Rosenberg, 2008).

![Fig.1: Diagrammatic representation of Piagetian Stages of cognitive development.](image-url)

Being a biologist he saw cognitive development as an ongoing process of biology. Just as food is digested in the body, Piaget contends that information is taken in by the human brain and digested in ways that also help the individual to survive.

To answer a question, on how an individual advances from one cognitive stage to another, Piaget responds by presenting three interrelated processes namely: assimilation, accommodation and equilibrium...
Assimilation involves incorporating new information into old ways of thinking or into existing schemes. In accommodation the child/learner has to fundamentally alter her/his old ways of thinking to adapt to the new information. Thus his/her schema of living things becomes more abstract as she/he focuses on such qualities as the ability to grow and reproduce. This change in thinking restores the child to a state of equilibrium in which the various pieces of knowledge all fit together.

Through accommodation and equilibrium, a child advances from Piaget's pre-operational period to a period of concrete operations and finally into the formal operations stage. Although some researchers such as Feldman (2008) have reported success in accelerating pre-operational stage, Piaget did not believe in pushing children ahead of their own developmental schedule. He presumed that children/learners should be allowed to grow at their own pace, with minimal adult interference (Elkind, 2010).

**Purpose of the Study**

This study seeks to explore the cognitive performance of form three and four learners on Piagetian Formal Operations Tests (PFOT) in Zimbabwe. It is guided by the following research question:

- How do Mutare urban “O” Level secondary school learners fare on a Piagetian Formal Operations Test modified to suit their nurturance as African children?

**METHODOLOGY**

**Research Design**

In this case study, some quantitative methodology aspects were implemented in form of a quasi-experimental format where a test was administered but no particular control group was identified. Some descriptive statistics were used to express the performance of the learners in the given test, the PFOT. Shadish et al. (2002) contend that quasi-experimental designs provide a reasonable control over most sources of invalidity and they are usually stronger than pure experimental designs. A pure experimental design would have a control group. The Piagetian Formal Operations Test (PFOT) as a research instrument was administered to pupils for purposes of trying to establish the cognitive developmental stage of learners.

**Population and sample**

From the total lot of secondary school pupils at the time of this enquiry, a total of 3,464 form 3 and 4 pupils from three secondary schools formed the accessible population from which a manageable sample of one hundred and ten (110) participants were randomly selected. There were many similarities between the target and accessible populations in the form of age groups, level of education, beliefs, home backgrounds, SES, languages and sizes of families. Because the target population was similar to the accessible population on a number of variables, there was good population validity of research results, meaning no population bias.

Random sampling was considered to be the best way to select a sample that was unbiased. In it, every member of the population has an equal chance of being chosen to be part of the group. However, this random sampling method can bring in possibilities of either a stronger or weaker concentration of high performers or vice-versa. This could endanger the reliability of the results. To counter this limitation a larger population sample was used to represent the secondary schools. Participants also came from three different schools. The 110 participants were randomly selected by asking form teachers to assist through use of pupil enrolment numbers. Girls were selected separately from the boys to ensure the maximum representation of each sex and avoid gender bias.

**Instrumentation**

The study made use of a Piagetian Formal Operations Test (PFOT) developed by Pisila Taute Ulungati, a specialist in Tests and measurements, from the University of Minnesota (Sprinthall and Sprinthall, 1994). A number of modifications and additions to the test were made to try and suit the local learner in Zimbabwe. To validate the PFOT, some subject specialists in English, ChiShona, Mathematics and Physical Science were consulted. The researchers are educational psychologists, therefore both validity and reliability of the research tool was established before use of the research tool.

The particular test designed for this study namely, PFOT, measured aspects of formal operations covering a logic problem made up of a puzzle where clues are provided to help learners to answer items 2 (i), 2(ii), 2(iii). Concrete thinkers may have difficulties remembering the clues and their explanations may indicate their inability to consider all clues simultaneously. Questions 3 and 4 covered physical property problems whilst
5, 6 and 7 measured spatial abilities. In as far as content validity is concerned, the test items did match the requirements of the “O” level Science and Mathematics syllabi used in Zimbabwe.

To ensure reliability, the idea of pilot testing the instruments to respondents with a similar background was one strategy. The test-retest reliability procedures were carried out at pilot level where participants assisted in identifying sections of the instruments that sounded vague or ambiguous. Corrections were made and retested. Any printing that showed threats to reliability were corrected for readability purposes as well as clarity.

RESULTS AND DISCUSSION

Performance of participants on the PFOT

The following table presents data to answer how the 110 secondary school pupils performed in a Piagetian Formal Operations Test (PFOT). The PFOT was a research instrument used to test abstract thinking and other aspects of formal operations stage of Piaget’s cognitive developmental theory. Participants had to answer three compulsory questions which were basically Logic problem, Physical property problems, and Spatial abilities.

<table>
<thead>
<tr>
<th>Scores in Rank-Order</th>
<th>Frequencies (F)</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>84%</td>
<td>1</td>
<td>0,91%</td>
</tr>
<tr>
<td>76%</td>
<td>1</td>
<td>0,91%</td>
</tr>
<tr>
<td>68%</td>
<td>1</td>
<td>0,91%</td>
</tr>
<tr>
<td>64%</td>
<td>2</td>
<td>1,81%</td>
</tr>
<tr>
<td>60%</td>
<td>1</td>
<td>0,91%</td>
</tr>
<tr>
<td>56%</td>
<td>5</td>
<td>4,54%</td>
</tr>
<tr>
<td>52%</td>
<td>9</td>
<td>8,18%</td>
</tr>
<tr>
<td>48%</td>
<td>10</td>
<td>9%</td>
</tr>
<tr>
<td>44%</td>
<td>9</td>
<td>8,18%</td>
</tr>
<tr>
<td>40%</td>
<td>11</td>
<td>10%</td>
</tr>
<tr>
<td>36%</td>
<td>15</td>
<td>13,64%</td>
</tr>
<tr>
<td>32%</td>
<td>23</td>
<td>20,90%</td>
</tr>
<tr>
<td>28%</td>
<td>10</td>
<td>9%</td>
</tr>
<tr>
<td>24%</td>
<td>4</td>
<td>3,63%</td>
</tr>
<tr>
<td>20%</td>
<td>8</td>
<td>7,27%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>n = 110</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

Note: Percentages add up to 100 for the last column (allowing for rounding off errors).

From the three urban secondary schools, the performance on PFOT was mostly concentrated on a score of 32% representing the mode. The mean score (\( \bar{x} \)) was 39% whilst the median was 36%. The three measures of central tendency provided a general location of the distribution which seemed to be skewed towards the lower half. The calculated sample standard deviation was found to be 12, 19. The histogram also reflects a normal distribution curve where it appears that as the scores rose, the frequencies were decreased.
The general performance of learners on the Piagetian Formal Operations Test (PFOT) was rather low as reflected in Table 2 and Fig. 1. Only 20 of the 110 participants, i.e., 18 (8%) scored above 50% indicating that most learners scored below half of the total number of scores in the test. This could denote that thousands of other young children are failing to reach their potential in cognitive performance. The finding is consistent with Shayer et al. (1976) who concur with Ohuche and Otaala (1986) both in Mwamwenda (1990) that only a small fraction of secondary school pupils in Africa can reach Piaget’s formal operations stage in cognition. Generally, the learners reflected more of concrete operations than formal operations in the manner they tackled some of the PFOT items. On a more positive note, however, participants showed some understanding of difficult grammar concepts, a skill that Piaget claimed as a reflection of formal operations thought. Many of the participants reflected this skill in the manner they tackled the PFOT. From this finding, it is evident that the teachings and interactions from the home environment do reflect a lot of difficult grammar concepts. Teachers should reinforce this knowledge in schools.

Within the PFOT, evidence of ‘animism’ was reflected where participants perceived the Bean, Bird and Snail Islands in the logic problem as mere living things instead of Islands (Ganga, 2011). Animism, according to Piaget, is one aspect of concrete operational behaviour where a person believes that all things are living and are capable of intentions, consciousness and feelings. This could imply that our teaching and learning systems should expose learners to instances where they are able to differentiate living and non-living in more abstract terms.

There was also some evidence of lack of critical thinking where most participants failed to explain their response fully or justify even with some given clues. This indicated that participants lacked a systematic formulation of concepts and failure to reason deductively. Learners should therefore, be exposed to many tasks in the school curriculum that would involve them more into deductive reasoning and some critical thinking since these are representative of formal operational thoughts.

In presenting answers on the spatial ability problems, many of the learners reflected lack of conservation, another quality in which Piaget expected his participants to recognise that quantities and volumes can remain constant as reflected in the Physical property problem of the PFOT. For instance, some learners could not simply conceptualise that $8 \times 2 = 4 \times 4$ in order to tackle the problem on the ‘principle of moments’. On the same note, very few could conceptualise the fact that one oscillation/cycle would depend on the length of the pendulum. Perhaps the problem could be emanating from lack of exposure to similar tasks inside class or at home.

More participants were however, able to reflect some reversibility mastery and some relational concepts in the spatial ability tasks. Being able to solve some relational concepts in geometrical problems about shapes without reference to concrete representations is one aspect that Piaget saw as evidence of formal operations in his participants. From the number who managed the tasks on spatial ability, it can be deduced that perhaps these tasks are much more familiar in the school’s curriculum. The manner the tasks are developed from lower grades to higher ones makes it possible to assist learners to move from concrete operations to more formal operational behaviour in learning.

A more recent finding by Prophet and Vlaardingerbroek (2003) on the Piagetian status of some one hundred and seventy five (175) Botswana secondary school pupils using the Science Reasoning Tasks (SRT), also acknowledged that cognitive levels of some students at secondary school level was late concrete operational thinking at 38% and 62% below concrete operations. No students were found to be capable of formal operational thinking. It is however, encouraging to note that 18 (8%) of the participants in this study passed the PFOT indicating that it is possible for some learners to reach formal operations thoughts at certain levels especially if the content tested is linked to the learners environmental experiences.

Educationists or researchers should think of the learner’s Zone of Proximal Development (ZPD) suggested by Vygotsky (1978) in Wolfolk (2004). He talks of the importance of helping learners to construct understanding and moving cognitively. Piagetian tasks tend to test the reasoning capacity at a particular point but do not say much about social constructivism. This remains a challenge for curriculum developers and educators. Many learners are striving to reach their highest cognitive levels, yet there are many intervening variables within their homes that seem to be playing greater roles.

**Performance of participants on each item in the PFOT**

The following data presents performance of participants on each item of the PFOT.
More concentration is on failure rate at 78% whilst 7% did not attempt to answer the task. The pie chart is best suited to present the details on the logic problem so that readers can compare the high failure rate with the low pass rate on the logic problem.

The Logic problem was made up of a developmental question with clues for answering. Even with the given clues, some participants failed to get the logic problem right. The task had a high cognitive demand where participants should have shown capability in formal operational thought, had they managed to solve the puzzle. In fact, some participants went on to believe that the four objects forming the islands were living organisms, an indication of concrete operational thought, yet they were merely pieces of land on which the plane could land. One may want to think that failure in this instance was due to the fact that the children were not fully familiar with such cognitive tests.

The major obstacle on familiarity as suggested earlier on by Otaala (1973) in Mwamwenda (2004) remained a reducing factor. In fact, most participants reflected concrete operational thoughts here, where they seemed so confused that they ended up giving literal meanings to the Piagetian puzzle. This supports Ulungati’s contention in Sprinthall and Sprinthall (1994) that some learners who are still at concrete operations level in thoughts can easily be identified by the manner in which they provide responses. No abstract thoughts were reflected in the greater percentage of the 78% who failed the task as shown in fig. 3.

In order to show formal operations as suggested by Piaget, participants would need to shift their thinking upwards through the cognitive levels. This could be enhanced by carefully planned learning programmes where the learner is assisted at home and school by creating a conducive learning environment.

**Performance of Participants on items 3 and 4 of the PFOT (Physical Properties Problems)**

<table>
<thead>
<tr>
<th>Quest No.</th>
<th>Pass (f)</th>
<th>%</th>
<th>Fail (n)</th>
<th>%</th>
<th>Did not attempt the question (n)</th>
<th>%</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>74</td>
<td>67%</td>
<td>30</td>
<td>28%</td>
<td>6</td>
<td>5%</td>
<td>110</td>
</tr>
<tr>
<td>4</td>
<td>35</td>
<td>32%</td>
<td>65</td>
<td>59%</td>
<td>10</td>
<td>9%</td>
<td>110</td>
</tr>
</tbody>
</table>

From table 2 above, 67% of the participants passed item 3 whilst 28% failed the task. Six (6) participants did not attempt question 3. It was almost vice-versa with item 4 where 32% passed and 59% failed indicating more level of difficulty in item 4 of the physical property problems. The two questions involved aspects of ‘the principle of
moments’ as well as ‘the pendulum’. The participants seem to have performed much better in the 3rd question than the 4th giving an indication that they could be much more familiar with the principle of moments than the pendulum. This finding brings forth a clue that learners can show formal operations in one aspect yet in another, they do not. This is evidenced by the reflections in table 2. The implication therefore, is that teachers need to cover, with learners, all syllabi topics in full, for most of these so called Piagetian tasks are linked to requirements of the school syllabus at certain levels.

Once more, the performance on the rather tough tasks in question 3 and 4 of the PFOT demonstrates the strength of cognition in Zimbabweans whose environment at home and at school can sometimes be contradictory. For instance, whilst some teachers may urge their learners to complete homework before coming to school, some illiterate parents urge their children to complete all school work at school and to leave the home for household chores. The whole idea leaves the learner in an awkward situation that may certainly hinder progress in learning.

Performance of participants on items 5, 6 problems and 7 (spatial ability)

Table 3: pass/fail for questions 5, 6, and 7 in PFOT

<table>
<thead>
<tr>
<th>Questions</th>
<th>Pass</th>
<th>%</th>
<th>Fail</th>
<th>%</th>
<th>Did not attempt Questions</th>
<th>%</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>68</td>
<td>61.8</td>
<td>35</td>
<td>31.8</td>
<td>7</td>
<td>6.4</td>
<td>110</td>
</tr>
<tr>
<td>6</td>
<td>33</td>
<td>30</td>
<td>64</td>
<td>58.1</td>
<td>13</td>
<td>12</td>
<td>110</td>
</tr>
<tr>
<td>7</td>
<td>34</td>
<td>30</td>
<td>63</td>
<td>57.2</td>
<td>13</td>
<td>12</td>
<td>110</td>
</tr>
</tbody>
</table>

The first two items (items 5 and 6) in table 5 involved counting of shapes whilst question 7 involved calculation of area in square centimetres. Thirteen (13) participants did not attempt 6 and 7. More participants passed question 5 with 3 (5%) failing to locate the exact number of triangles. A greater number failed spatial ability tasks in question 6 and 7 at a failure rate of 58 (1%) and 57 (2%) respectively. Twelve percent (12%) in each case did not tackle the tasks.

The spatial ability problems were not well done with a greater percentage failing to count shapes within a given area of shapes. This reflected failure on the conservation of area by participants as in Duroijaiye’s (1990) cross-cultural study with 60 Nigerians of different ethnic groups. He concluded that conservation of area is the most difficult as compared to conservation of liquid, substance and number, regardless of whatever ethnic group one belongs to. Perhaps the variegated performance on the spatial ability tasks was also due to the type of the sample selected. A mixed ability sample was selected. In some instances, participants performed lowly as implied by the histogram in Fig 2. It is vital for educational psychologists to remember to plan variegated tasks in order to cater for all backgrounds of learners who may be involved in writing the test.

However, as for the greater number of participants who scored highly in question 5 under spatial ability problems, it clearly reflects that our learners can perform wonders in some areas of formal operational tasks though they may falter in others. In such cases, a contradiction may arise with previous research findings that African children may never reach formal operational thought as was claimed by Shayer et al. in Mwamwenda (2004). The findings on the performance of participants in the PFOT reinforces some clues that in certain tasks, learners can show formal operational thought, yet in others they do not. Perhaps the effects of such could be their age level and experiences within the environment or other factors that may require further investigations. With this in mind, let us briefly compare the performance of participants on the PFOT by their age and gender.

Comparing performance on PFOT by age and gender

The component bar graph in fig. 4 below represents the 65 pupils out of 110 who scored above the mean (x = 39%) in the PFOT. This particular method of presentation (a component bar graph) is ideal to compare performance through use of two variables (age and gender) so that readers clearly view the differences in performance as indicated by the two components represented by the key.
From each age level represented in Fig. 3 above, it is evident that the greater number of participants who scored above the mean seemed to be rising with age. For instance, there is evidence that within the 16-year age group, there are greater number of participants who scored above the mean than ages 14 and 15 years. Within the 15-year component as well as the 16 and 17 year group, a greater number of boys seemed to have performed much better than the girls. Could this be implying that boys are better performers than the girls as far as Piagetian cognitive tasks are concerned?

This finding that older participants (mostly boys) seemed to have performed much better than girls as represented in Fig. 3 above, clearly denotes that besides the home environment, there are other factors involved in cognition i.e. age and experience. The finding remains consistent with Llyd (1971) in Mwamwenda's (2004) finding on the Yoruba children in Nigeria who were tested on conservation of number. The fact that boys still remain outperforming girls as in Fig. 3, clearly demonstrates that the child-rearing practices where boys tend to be exposed more to duties related to Piagetian tasks than girls, remains a great challenge to all parents. However, nowadays, one may argue that the household chores meant for the girl-child are now being shared by both sexes in most homes. The girl-child is also exposed to man’s chores in order to bring about gender equity. Perhaps, there could be a possibility that the random sampling employed might have accidentally concentrated on weaker girls even if the sample shows gender balance. Further research into this area could be more ideal.

However, Irvine (1979) in Berry and Dasen (2001) warns researchers that they should not conclude that one lacks a good cognition process because of lack of verbal evidence or presence of it. There could be other intervening variables such as size of one’s family, education level of parents, S.E.S. or home language as contributory factors to a child’s success or failure. This implies that there is need for further research into the home environmental variables with regards to how each contributes to a child’s cognition.

**RECOMMENDATIONS**

Basing on the above presentation and discussion of findings, the following recommendations are available:

- A replication of this study could be carried out in other cities and also with the rural learners in order to enable researchers to generalise further, findings on the cognitive performance of learners on PFOT.
- More cognitive tests to suit the African child should be constructed by specialists in order to appropriately place the level of cognition for the African child.
- Further modifications and validations into the PFOT itself and other cognitive tests used by psychologists are necessary in order to produce more valid and reliable findings.
- Psychologists should take note of the aspect of familiarity and culture-fairness in test items.
• Parents/Guardians and teachers should show appreciation of whatever fraction of effort is shown by the learner in academic work, because motivation is a vital component if learners are to attain high academic excellence.

REFERENCES