Assessment of Students’ Procedural and Conceptual Knowledge of Algebra in Colleges of Education in Kano State

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Authors’ contributions

This work was carried out in collaboration between both authors. Author SOA design the study, performed the statistical analysis, wrote the protocol and the first draft of the manuscript. Author CT A managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

This study assessed students’ procedural and conceptual knowledge of algebra in colleges of education in Kano State. The design of the study was panel survey research design. Three research questions were raised and three hypotheses were formulated to guide the study. The population was 790 NCE1 students of Mathematics combinations from eight colleges of education with a sample size of 236 students using multistage sampling technique. Two-tier Diagnostics Test Items Cycle I and Cycle II with a reliability coefficient of 0.75 were used for data collection. Mean and standard deviation was used to answer research questions, while t-test statistics were used to test the null hypotheses at 0.05 level of significance. Findings revealed that there exists a significant difference between the mean achievement scores of students in procedural knowledge and conceptual knowledge in algebra (P < 0.05). It was also revealed that procedural and conceptual knowledge of male and female students in algebra did not significantly differ (P > 0.05). Based on the findings, it was recommended that conferences and workshops should be organized...
1. INTRODUCTION

Mathematics is defined as a way of describing relationships between numbers and other measurable quantities [1]. It is used to express simple equations as well as interactions among the smallest particles and the farthest objects in the known universe. Mathematics can also be seen as the study of quantity, magnitude and relations of numbers or symbols [2]. It embraces the concepts of arithmetic, geometry, algebra, calculus, probability, statistics, set theory, trigonometry and other special areas of research. There are two major divisions of Mathematics. These include: pure and Applied Mathematics. Pure Mathematics investigates the subject solely for its theoretical interest while applied Mathematics develops tools and techniques for solving specific problems of business and engineering or for real-life applications in the sciences [1]. Mathematics allows scientists to communicate ideas using the universally accepted terminology of numbers and symbols. It is basically the study of patterns. The process of teaching and learning Mathematics provides the child with a wide range of knowledge, skills and related activities that help to develop an understanding of the physical world and social interactions [3]. The application of Mathematics in a variety of contexts gives people the ability to explain, predict and record aspects of the physical environment and social interactions. It enriches the understanding of the world in which people live [4]. Mathematics trains a child to acquire critical reasoning, numerical skills and other needs for effective and sustainable independent life. These include the need for interest and meaningful mathematical experiences, apply Mathematics in other areas of learning, continue studying Mathematics at the post-secondary level, and become mathematically literate members of society [3]. Mathematics generally helps to increases students’ reasoning skills through critical reasoning and reflective thinking. These skills can be obtained from all branches of mathematics such as calculus, trigonometry, statistics, set theory, operational research, and probability. Others include ring, geometry, vector analysis, real analysis, number theory, complex numbers, and algebra. However, this study focuses on algebra because algebra uses symbols to represent a variable. These symbols or letters can be used in almost all branches of mathematics and science. Algebra is seen as a major branch of mathematics that gives support to other branches of mathematics and science in terms of critical thinking and calculation [5].

Algebra is derived from the Arabic word al-jebir meaning “reunion of broken parts”. It is the branch of Mathematics that uses symbols to represent arithmetic operations [6]. Algebra guides students to understand other branches of mathematics because it uses letters to represent numerical values. The basic parts of algebra are called elementary algebra. The advanced parts are called abstract algebra or modern algebra. Elementary algebra is essential for any study of Mathematics, science or engineering as well as applications such as medicine, engineering, and economics. Abstract algebra is a major area in advanced Mathematics. It is studied primarily by professional mathematicians and mathematics educators. Among the concepts studied by modern algebra are groups, rings, and fields. Algebra allows proof of properties that are true no matter which numbers are involved. An algebraic expression is a mathematical sentence written with letter(s) or symbol(s) and operational sign(s) without equal sign such as $3x^2 + 2xy + c$. However when an equality sign is introduced in an expression, it becomes an algebraic equation. Examples include: $3x^2 - 2xy + C = 0$, $7x + 5y + 3x + 4 = 23$, $7x + 3 - 2x = 7$, $10xp + 4p - 2x = 4$.

Students’ achievement in mathematics has consistently been low as observed by Olayinka, [7] and Aligba, [8]. Evidence are bound that students’ low achievement in mathematics is attributed to poor knowledge in algebra. For example, Ugwu [5] observes that lack of...
knowledge in algebra affects students’ achievement in mathematics, science, and science-related courses. Also, Shidhu [9], Useni, Okolo, and Yakubu, [10] have stated that the persistent poor achievement of students in algebra is responsible for the high failure in Mathematics which generates much concern by stakeholders both in Nigeria and at international level. Odili [11] states that the difficulty students encounter in understanding the first work of algebra is due to the sudden switch over from arithmetic to a quantitative relationship with the new system of symbolization.

Students’ low achievement in algebra has been attributed to the poor state of teaching and learning process in Nigerian schools which is a serious indictment on secondary and other levels of education in Nigeria (Useni, Okolo & Yakubu, [10]). Nurudeen [12] reports that teacher’s teaching strategies and methods contribute immensely to the poor achievement of students in algebra and mathematics. This problem of low achievement of students in algebra is a general concern of everybody in the society. Obodo [13] supports this by adding that generally, there is a low interest in the study of algebra and Mathematics related disciplines at all levels of educations in Nigeria. Hence, the need to use an effective method of teaching algebra and mathematics by mathematics teachers becomes paramount.

In every teaching and learning situation in algebra and Mathematics, procedural and conceptual knowledge are very important for skills acquisition. These skills explain in clear terms methods, steps and patterns students are expected to follow so as to acquire permanent algebraic knowledge. Procedural knowledge provides logical patterns and strategies for solving an algebraic equation. It means memorizing only the methods or steps that are involved in a phenomenon or concept [14]. In algebra, procedural knowledge refers to a process where someone memorizes only the method or formula of an algebraic expression or equation without recognizing the reasons behind the why or how each step is obtained.

Conceptual knowledge is the systematic and mental understanding of a phenomenon or content [14]. In other words, it involves acquiring mental procedural analysis and understanding of a concept through underlining reasoning. The conceptual understanding of algebra refers to acquiring mental procedural knowledge and underlining reasoning of a real meaning of algebraic equations or expressions. Lee [15] observes that conceptual knowledge is the mental knowledge of theories, principles, proofs, and structures in a particular discipline.

The procedural and conceptual understanding of male and female students was also observed by the researchers in this study. This might help both males and females to compare their differences and improve their academic achievement. In some schools, female students achieved better than male students. In other schools, the reverse is the case [16]. A research conducted by Sara, Janet and Jennifer [17] on new trends in gender and Mathematics achievement at the University of Wisconsin – Madison supports the view that males and females achieved similarly in Mathematics. In addition, Bello [18] observes that female education is a very important determinant of any family development and improvement. Hyde and Mertz [19] suggest that government and parents should increase educational opportunities appropriate for females by providing more single-sex science schools at all levels. Gender study is necessary for academic achievement in different fields. Therefore, this study found out whether or not students’ conceptual and procedural understanding of algebra is gender-biased.

2. STATEMENT OF THE PROBLEM

Over the years, Students’ academic achievement in mathematics has consistently been low. A research conducted by Adewumi [20] revealed that students’ performance and achievement in Mathematics at the final year examination of West African Examinations Council (WAEC, [21]) was not encouraging. Besides, analysis of NCE I students’ achievement in MAT III for ten consecutive years showed that only 25% of candidates passed the course with C and above. This shows low achievement. Parents, teachers, government, and non-governmental organizations, as well as other stakeholders, have great concern over the low achievement of students in algebra in particular and mathematics in general. What could happen in future if most students lose hope in studying Mathematics because of low performance and achievement? What could happen to our country if most students drop out of school because of low performance and achievement in Mathematics? The low achievement could lead to students’ drop out, underdevelopment of societies,
corruption, armed robbery, sexual harassment, drug abuse and terrorism. Therefore, it was imperative to assess students’ level of procedural and conceptual knowledge in algebra and provide a possible remedy where necessary.

2.1 Purpose of the Study

The purpose of this study was to assess students’ level of procedural and conceptual knowledge of algebra in colleges of education in Kano State. The objectives of the study were to:

i. Assess students’ level of procedural knowledge in algebra.
ii. Ascertain students’ level of conceptual knowledge in algebra.
iii. Determine male and female students’ level of procedural knowledge in algebra.
iv. Ascertain male and female students’ level of conceptual knowledge in algebra.

2.2 Research Questions

The following research questions guided this study:

1. What is the level of students’ procedural knowledge and conceptual knowledge in algebra?
2. What is the level of procedural understanding of male and female students in algebra?
3. What is the level of conceptual understanding of male and female students in algebra?

2.3 Hypotheses

The following null hypotheses were formulated and tested at 0.05 level of significance:

H₀₁: There is no significant difference in the mean achievement scores of students in procedural knowledge and conceptual knowledge in algebra.

H₀₂: There is no significant difference in the mean achievement scores in the procedural knowledge of male and female students in algebra.

H₀₃: There is no significant difference in the mean achievement scores of conceptual knowledge of male and female students in algebra.

2.4 Research Design

The research design for this study was panel survey research design. It is the type of research design which employs a defined procedural or techniques of collecting data from a given sample at two or more different periods [22]. The choice of panel survey for this study was to allow the researcher collect data by using ‘two-tier test’ items in the first and second cycles respectively. The reason for collecting data in two cycles was that in the first cycle, students’ answers (reasoning) were used to develop the second part of the second cycle in an objective format.

2.5 Area of Study

The area of this study was Kano State. Kano State is located in north-western Nigeria. It was created on May 27, 1967, from part of the Northern Region. Kano State borders Katsina State to the north-west, Jigawa State to the north-east, Bauchi State to the south-east and Kaduna State to the south-west. The capital of Kano State is Kano. According to 2006 census, Kano State has a population of 9,383,682. It is located at latitude 13° 2’ 0” N and longitude 4°24’ 0” E (Abubakar, [23]). The state is mostly populated by Hausa and Fulani people. There are eight colleges of education in Kano State. Each of them has abysmally low achievement in MAT III. Available records show that there is no empirical evidence to assess students’ level of procedural and conceptual knowledge of algebra in colleges of education, particularly in Kano State. Hence, the need for this study becomes paramount.

2.6 Population

The population of this study included 790 NCE1 students of Mathematics combinations from the eight colleges of education in Kano State while the population of the three colleges of education whose students participated in the study was 501. The figure was obtained from the office of Head of Departments, Mathematics admission list of 2015/2016 from the respective schools by the researcher.

2.7 Sample and Sampling

The sample consisted of 236 students from three colleges of education for the study. The three colleges of education selected were: Federal College of Education (Technical) Bichi Kano,
2.10 Reliability

In order to test the reliability of the instruments, 40 students from Annur College of Education Kargon, Bichi, Kano State were involved in the study. The researchers used multistage sampling techniques for the study. At the first stage, proportionate stratified random sampling technique was used to determine the sample size of students in each of the respective schools and departments. That is, a sample of 67 was drawn from 143 students of Federal College of Education (Technical) Bichi Kano, 90 was selected from 191 students of Federal College of Education, Kano and 79 were drawn from 167 students of Saadatu Rimi College of Education, Kumbotso Kano. Systematic sampling was used to select students that participated in the study.

2.8 Instrumentation

The instrument used in this study for data collection was a Two-tier test. It was a researcher-developed 20-item test that was designed to assess students’ procedural and conceptual knowledge in algebra. The two-tier test was divided into two cycles which included: Two-tier Diagnosis Test Cycle I (TDTCI) and Two-tier Diagnosis Test Cycle II (TDTCII). In the first cycle, 20 items were developed by the researcher based on the content of algebra (MAT III) of NCE I. It contained part I and part II. Part I contained 20 objectives items while part II contained 20 open questions which required students to give reasons to support the answer in part I. The answers in form of justifications that students produced were used by the researcher to develop the second part of the second cycle in objective form with options from A-D.

2.9 Validation of Instruments

The Two-tier Test Items for Cycle I and Cycle II were validated by three experts in Mathematics Education at Benue State University, Makurdi. The experts validated the items based on whether or not the instruments conformed with the subject matter they were supposed to test, the items covered the basic idea and variables of the study, the items are adequately capable of providing answers to the research questions and hypotheses of the study and the items were designed to use correct statistical tool for data analysis.

For effective administration and collection of data, the researchers trained one research assistant in each school for one week to help in administering and collecting instruments. In the first cycle, the researchers visited the respective schools and presented an introduction letter to the Dean of Science Education who accepted the researchers and directed them to the Head of Department Mathematics. The H.O.D further took the researchers to the required students with the help of research assistant for administration and collection of the instruments. The researchers explained the purpose of the research to the students to understand that the research had neither health hazard nor monetary reward to the participating students so that the choice to participate was theirs. Furthermore, the researchers explained to students how to answer the test items and advised them to feel free with the answers because they would be used for field work. Students were allowed to ask questions where necessary. Answers were also provided to them accordingly. The test was administered, supervised and collected by the researchers and the research assistant. To collect data for the second time using two-tier test items cycle II, the researchers visited the same schools for the second time with the help of research assistants of the respective schools for administration and collection. Data collected from two-tier test items cycle II were used for final analysis.

4. METHOD OF DATA ANALYSIS

Data collected were analyzed, mean and standard deviation was used to answer research questions, while t-test statistic was used to test the null hypotheses at 0.05 level of significance. The reason for using t-test statistic for hypotheses testing was based on the fact that
both the research questions and hypotheses were aimed at comparing means scores of two groups.

### Table 1. Summary of number of students

<table>
<thead>
<tr>
<th>Name of schools</th>
<th>No of two-tier test cycle II administered and collected</th>
</tr>
</thead>
<tbody>
<tr>
<td>F.C.E. (T) Bichi</td>
<td>67</td>
</tr>
<tr>
<td>F.C.E Kano</td>
<td>90</td>
</tr>
<tr>
<td>Saadatu Rimi C.O.C.</td>
<td>79</td>
</tr>
<tr>
<td>Kumbotso</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>236</td>
</tr>
</tbody>
</table>

Table 1 gives the number of two-tier test cycle II instruments administered and collected. The analysis is based on the sample of 236 students.

### 4.1 Research question 1

What is the level of students’ procedural knowledge and conceptual knowledge in algebra?

Table 2 shows that the mean score of students in conceptual knowledge was 8.69 and the standard deviation was 2.45 while the mean score of students in procedural knowledge was 16.50 and the standard deviation was 3.15. This indicates that the level of students’ conceptual knowledge was low and the level of students’ procedural knowledge was high. This implies that the students had high procedural knowledge which was above average in a test score of 20 marks, while their conceptual knowledge was low below average in a test score of 20 marks. The standard deviation of students in conceptual knowledge was relatively low compare to those of procedural knowledge indicating that the performance of students in conceptual knowledge was more homogeneous than those of procedural knowledge.

### Table 2. Mean scores and standard deviation of students’ level of conceptual and procedural knowledge in algebra

<table>
<thead>
<tr>
<th>Title</th>
<th>N</th>
<th>Scores</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conc. Knowledge</td>
<td>236</td>
<td>2052</td>
<td>8.69</td>
<td>2.45</td>
</tr>
<tr>
<td>Pro. Knowledge</td>
<td>236</td>
<td>3884</td>
<td>16.50</td>
<td>3.15</td>
</tr>
</tbody>
</table>

### 4.2 Research Question 2

What is the level of procedural understanding of male and female students in algebra?

Table 3 shows that the mean score of male students in procedural knowledge was 16.22 while the standard deviation was 3.30. Similarly, the mean score of female students was 17.11 and the standard deviation was 2.62. This means that the level of procedural understanding of male and female students was above average in a test score of 20 marks. It also implies high achievement for both male and female students. However, female students’ scores were higher than the male students’ scores. At the same time, the performance of the female students was more homogeneous than the male students.

### Table 3. Mean scores and standard deviation of students in procedural knowledge of male and female students in algebra

<table>
<thead>
<tr>
<th>Gender</th>
<th>N</th>
<th>Scores</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>172</td>
<td>2789</td>
<td>16.22</td>
<td>3.30</td>
</tr>
<tr>
<td>Female</td>
<td>64</td>
<td>1095</td>
<td>17.11</td>
<td>2.62</td>
</tr>
</tbody>
</table>

### 4.3 Research Question 3

What is the level of conceptual understanding of male and female students in algebra?

Table 4 reveals that the mean score of male students in conceptual knowledge was 8.85 and the standard deviation was 2.49. The mean score of female students was 8.28 with a standard deviation of 2.29. This shows that the level of conceptual understanding of male and female students was below average in a test score of 20 marks. This means low achievement in the conceptual knowledge of algebra for both male and female students.

### Table 4. Mean scores and standard deviation of students in conceptual knowledge of male and female students in algebra

<table>
<thead>
<tr>
<th>Gender</th>
<th>N</th>
<th>Scores</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>172</td>
<td>1522</td>
<td>8.85</td>
<td>2.49</td>
</tr>
<tr>
<td>Female</td>
<td>64</td>
<td>530</td>
<td>8.28</td>
<td>2.29</td>
</tr>
</tbody>
</table>

### 4.4 Hypothesis One

There is no significant difference in the mean achievement scores of students in procedural knowledge and conceptual knowledge in algebra.

Table 5 shows that $t (470) = 2.99; P < 0.05$. The probability value was less than 0.05 indicating a significant difference in the mean achievement scores of students in procedural knowledge and conceptual knowledge in algebra in favor of procedural knowledge. That is, Students’
Table 5. Independent t-test analysis of procedural and conceptual knowledge of students in algebra

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>St. deviation</th>
<th>df</th>
<th>t</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pro. Know</td>
<td>236</td>
<td>16.46</td>
<td>3.15</td>
<td>470</td>
<td>2.99</td>
<td>0.001</td>
</tr>
<tr>
<td>Conc. Know</td>
<td>236</td>
<td>8.69</td>
<td>2.45</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6. Dependent t-test analysis on procedural knowledge of males and female students in algebra

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>St. deviation</th>
<th>df</th>
<th>t</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>172</td>
<td>16.22</td>
<td>3.30</td>
<td>234</td>
<td>1.95</td>
<td>0.052</td>
</tr>
<tr>
<td>Females</td>
<td>64</td>
<td>17.11</td>
<td>2.62</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 7. Dependent t-test analysis on conceptual knowledge of males and females students in algebra

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>St. deviation</th>
<th>df</th>
<th>t</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>172</td>
<td>8.85</td>
<td>2.49</td>
<td>234</td>
<td>1.59</td>
<td>0.113</td>
</tr>
<tr>
<td>Females</td>
<td>64</td>
<td>8.28</td>
<td>2.29</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

achievement in procedural knowledge was better than conceptual knowledge. Therefore, the null hypothesis was rejected. The implication is that there is a significant difference in the mean achievement scores of students in procedural knowledge and conceptual knowledge in algebra in favor of procedural knowledge.

4.5 Hypothesis Two

There is no significant difference in the mean achievement scores in the procedural knowledge of male and female students in algebra.

Table 6 reveals that $t(234) = 1.95; P > 0.05$. As the probability value was greater than 0.05, it indicates no significant difference in the mean achievement scores in the procedural knowledge of male and female students in algebra. Therefore, the null hypothesis was not rejected. This means that there is no significant difference between mean achievements scores of procedural knowledge of male and female students in algebra.

4.6 Hypothesis Three

There is no significant difference in the mean achievement scores of conceptual understanding of male and female students in algebra.

Table 7 reveals that $t(234) = 1.59; P > 0.05$. Since the probability value was greater than 0.05, it indicates no significant difference in the mean achievement scores in the conceptual knowledge of male and female students in algebra. Therefore, the null hypothesis was not rejected. This means that there is no significant difference between conceptual knowledge of male and female students in algebra.

5. DISCUSSION OF FINDINGS

Findings revealed that the level of students’ understanding of procedural knowledge of algebra was relatively high, and above average, in a test score of 20 marks while the level of students’ understanding in the conceptual knowledge of algebra was relatively low and below average in a test score of 20 marks. This means that students have little mathematical mental reasoning skills of concept but had memorized process and formulas of solving algebraic equations. This finding agrees with Hong [24] and Amanda and Willson [25] who found that students’ level of conceptual understanding was low. The agreement could be as a result of the fact that most students study for the purpose of passing examination only and not for the purpose of applying the knowledge. The implication of this finding is that a number of mathematics students will not be able to apply mathematics knowledge to solve real-life problems which are not healthy for the education sector and nation-building. It is worthy of note that students’ understanding of the conceptual knowledge of algebra needs to be as high as that of procedural knowledge. It is in line with this that Rittleston-Johnson and Siegler [26] stated that there is a positive correlation between children’s understanding of mathematical concepts and their ability to execute procedures.
Findings also revealed that the level of procedural understanding of male and female students was above average. This indicated good performance and achievement. It also means that both male and female students can recall facts, formulae, and steps in an equation. This confirms the findings of Gozde, [27] in which both male and female students had high procedural knowledge in algebra. The findings also support Sara, Janet, and Jennifer, [17] who found that there is no difference in academic achievement of male and female students in Mathematics. The agreement could be as a result of the fact that most students learn Mathematics through methods and formulae processes.

Moreover, the findings indicate that the level of conceptual understanding of male and female students was below average. This implies that both male and female students had little mental skills to justify their steps and answers in solving algebraic equations. This is in conformity with Bonga, [28] who found that there is no significant difference between conceptual understanding of male and female students in algebra. The finding is also in agreement with Kalid, [29] who reported from a research that both male and female students had low conceptual knowledge in algebra. The agreement could be as a result of the fact that both male and female students studied under the same atmospheric condition and struggled to acquire the same knowledge and skills. This study created awareness that procedural and conceptual knowledge would help students to increase their academic achievement in algebra. It adds that conceptual knowledge would give rise to permanent knowledge. The study also stressed the need for using two-tier test and encourages teachers and examination bodies to include such in their examination questions.

6. RECOMMENDATIONS

Based on the findings of the study, it was recommended that:

1. Seminars, conferences, and workshops should be organized for in-service Mathematics teachers to keep them informed of the importance of procedural and conceptual knowledge in Mathematics and how to teach students to acquire such skills.
2. Both male and female students should be taught algebra in such a way as to acquire procedural and conceptual knowledge since the levels are gender friendly.

7. CONCLUSION

This study found that the level of students’ conceptual knowledge was lower than the level of students’ procedural knowledge in algebra. It was also found that the level of procedural understanding of male and female students was above average in a test score of 20 marks while that of conceptual understanding of male and female students was below average in a test score of 20 marks. This means low achievement in conceptual knowledge but high achievement procedural knowledge of algebra for both male and female students.

The study provides empirical evidence that procedural and conceptual knowledge would guide students to see the need of acquiring intellectual and logical reasoning skills so as to solve real-life problems. Therefore, it concluded that procedural and conceptual knowledge are necessary for enhancing achievement in algebra as one cannot progress academically without any of them. Hence, the need of learning algebra through procedural and conceptual knowledge cannot be overemphasized.

CONSENT

As per international standard or university standard, patient’s written consent has been collected and preserved by the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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### References

<table>
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<th>Author(s)</th>
<th>Title</th>
<th>Year</th>
<th>Available URL</th>
</tr>
</thead>
</table>

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