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The use of Instrumental Enrichment as a method to teach the analysis of the population pyramid to Grade 7 Geography students

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Abstract

Action research was conducted to improve the teaching of the analysis of the population pyramid to Grade 7 female Geography students. Instrumental Enrichment was selected as a tool to teach the analysis of the population pyramid. Firstly, the concept of a population pyramid was introduced and taught using an existing teaching method and a baseline assessment was conducted. Instrumental Enrichment was then introduced, and students used the tool to analyse four population pyramids. A concluding assessment measured the improvement in students' ability to analyse the population pyramid. The use of Instrumental Enrichment did enhance the students' understanding of the population pyramid. However, they were not able to use it consistently and independently. This agrees with Willingham (2009) that students remember what they think about and the findings of Bellaera (2017) and Adams (1991) that students are not able to develop critical thinking purely by interacting with the subject matter. A refinement of Instrumental Enrichment was proposed considering these principles.

Keywords: action research; population pyramid; Instrumental Enrichment; analysis; critical thinking

Introduction

An action research project was carried out in 2019 with Grade 7 female Geography students to answer the research question *"How might Instrumental Enrichment improve Grade 7 girls' ability to analyse the population pyramid?"* The school at which the project was carried out is an independent, urban school that caters for girls from Grade 0-12. The school writes the IEB Senior Certificate Examination. The topics of the Grade 7 Geography curriculum are derived from the CAPS document. The curriculum is enriched by presenting the material on population geography at greater depth than the requirements of CAPS. Population Geography is placed in a real-world context through case studies that describe challenges around population growth in specific countries. This enriched curriculum provides students with opportunities to think critically about the topic and use their knowledge to develop an understanding of current population problems. Four classes of Grade 7

students were taught the material as part of the action research project.

In Grade 7, students are expected to apply their knowledge of population concepts to the population pyramid. For example, they need to be able to use a population pyramid to identify and analyse the birth and death rates of a country or to describe the effect of events such as war or diseases on a population. Analysing the population pyramid is an important concept that is taught when population geography is studied. It is reinforced and expanded through the study of the demographics of different countries utilizing case studies. The following problems were identified during the teaching of the population pyramid to Grade 7 students during 2018:

- Students are not specific in referring to the bars on the population pyramid bar graph when motivating an answer, for example, when describing the birth rate, they say "the bars on the pyramid show this" or "the bottom bars show this" instead of "the bar from ages 0-4 shows…"
- Students make general statements such as "the bars on the pyramid decrease from age 20" or "the bars are short from age 75" when describing the life expectancy or death rate. These can be seen on any pyramid. They do not refer to the specific bar(s) on the pyramid where a change is observed by making statements such as, "there is a significant decrease from age 30" or "the bars only start becoming much shorter at age 70".
- Students do not describe what is observed on the pyramid when asked to describe the effect of an event on the pyramid.

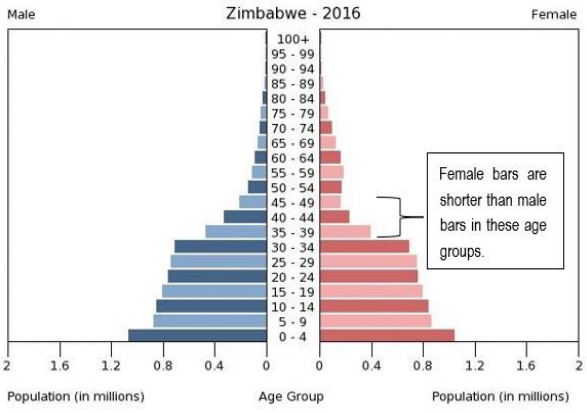

Figure 1: Population pyramid of Zimbabwe (After: Indexmundi, 2019c)

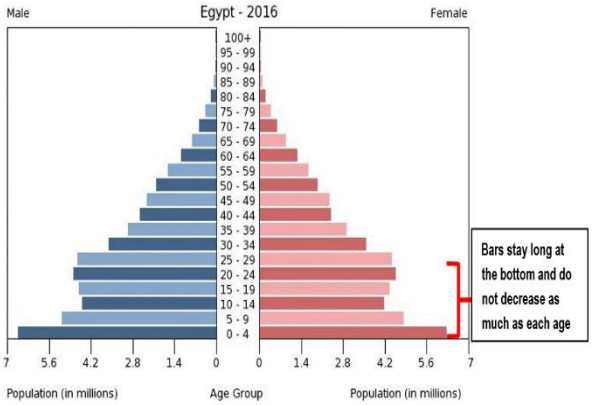

Figure 2: Population pyramid of Egypt (After: Indexmundi, 2019c)

For example, the Population pyramids of countries in sub-Saharan Africa, show a decrease in the number of females on the pyramid from age 25-50 due to HIV/AIDS An example of this is the population pyramid for Zimbabwe (Figure 1). When asked how the impact of AIDS can be seen on the pyramid, students do not refer to the specific age groups, instead refer to the ages 15-49, the age group most affected by AIDS.

The population pyramid for Egypt (Figure 2) shows a significant increase in the number of people younger than 35. This is due to an improvement in health care in the late 1970s that caused a decrease in the death rate. When asked how this decrease in the death rate can be seen on the pyramid, students are not able to identify that it happened from age 35.

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Action research project

An action research project was implemented in 2019 to find a better method to teach students the necessary skills to analyse a population pyramid.

A literature study was initially conducted. From the literature study, the method of Instrumental Enrichment (Link, 1991) was selected to teach analysis and the following research question was formulated: *How might Instrumental Enrichment improve Grade 7 girls' ability to analyse the population pyramid?*

Instrumental Enrichment is a program developed by the clinical psychologist Reuven Feuerstein. It aims to improve the cognitive ability of students through strategies that focus on the process of learning rather than specific skills and subject matter. The purpose of these intervention strategies is to assist students in the development of those cognitive functions that are a prerequisite to effective thinking (Link, 1991).

The research project was conducted according to the following method:

- The population concepts were introduced, and the material was taught using the existing teaching method.
- A baseline assessment was conducted.
- Instrumental Enrichment was introduced and used to teach the analysis of population pyramids.
- Data was gathered through observations.
- A concluding assessment was conducted and the results and answers to questions were compared with the baseline assessment.
- Conclusions were drawn as to the effectiveness of Instrumental Enrichment in the teaching of the analysis of the population pyramid.

It was decided to collect and assess data qualitatively and quantitatively to evaluate the effectiveness of Instrument Enrichment. The methods for selecting and analysing data were drawn from Mertler (2017).

Quantitative data

Baseline and concluding assessments were used to collect quantitative data to measure the effect of Instrumental Enrichment on the students' understanding of the material. The assessment used is normally administered when teaching the material to test students' understanding and interpretation of the population pyramid. The baseline and concluding assessments were based on similar population pyramids and similar questions were asked to determine if there was a change in students' understanding of the material as a result of using Instrumental Enrichment. Four classes were taught the material and class and grade averages were used to compare students' performance on the two assessments. It was decided to include all four classes in the quantitative analysis to reduce the impact of individual variations on the overall results by providing a larger sample size.

Qualitative data

Qualitative data were collected through observations as this provided the method to collect the most comprehensive data during the teaching process. Mertler (2017) describes observation as a process of carefully watching and systematically recording events in the classroom. As observations are general in nature and a normal part of the teaching process, they were conducted in all four classes. One of the four classes was randomly selected, and an in-depth qualitative analysis of their assessment results was conducted.

Mertler (2017) explains that qualitative data is analysed through the recognition of patterns.

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Data that provides similar information is grouped. Thereafter, the data is examined for relationships, similarities and contradictions. Connections are made between the data and the research question. Conclusions and interpretations are then drawn from this analysis.

This method was used to qualitatively analyse one class's answers to the baseline and concluding assessments. Conclusions were drawn from this analysis and these conclusions were then related to the research question and the literature study.

Literature survey

Willlingham (2009) explains that the brain is not good at thinking and is wired to avoid thinking if possible. People enjoy thinking and solving problems; however, these problems must not be too simple or too challenging, i.e. they must present some challenge but not too much. Teachers can use this principle to create interest in their students by presenting them with problems to solve that are slightly more difficult than their current ability.

The thought process

The process of thinking can be illustrated as shown in Figure 3.

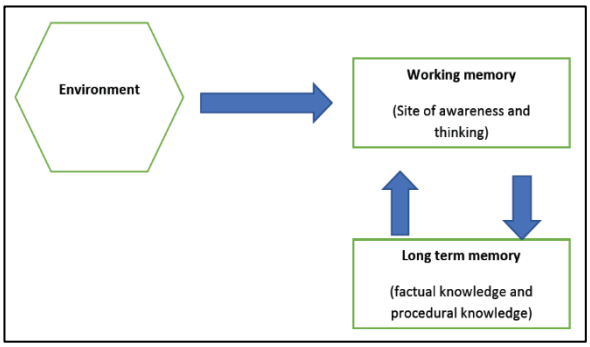

Figure 3: The thinking process (Willingham, 2009, p. 28)

Thinking occurs in working memory where information from the environment is combined in new ways with information in long term memory. Information stored in the long-term memory includes both facts and procedures. The following aspects need to be taken into consideration when designing lessons.

Working memory has an extremely limited capacity. Teachers need to respect the cognitive limits of students when giving them problems to solve. This can be done by:

- ensuring that students have enough background knowledge,
- limiting the demands placed on working memory when solving the problem, and
- developing questions to help clarify the problem.

Factual knowledge always precedes skill and thinking. For students to think, they must have something to think about. Factual knowledge must be memorised: students cannot use information that they have looked up as a basis for critical thinking. Thinking well requires knowing facts. Critical thinking processes are intertwined with knowledge in long term memory, not in the environment.

Lessons must be designed around what students need to think about for them to remember and learn the material. As working memory is limited, students will not spend equal amounts of time thinking about all aspects of the lesson. Care must be taken to ensure that lesson design does not distract students from the material that they most need to think about to meaningfully retain the information. Willingham (2009) gives an example of a History lesson where students were required to give a presentation on PowerPoint and focussed on the features of PowerPoint rather than the History content.

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He says that this lesson was unsuccessful because the students were not thinking about the information that they needed to remember during the lesson.

Shallow and deep knowledge

Willingham (2009) makes a distinction between shallow knowledge and deep knowledge. Shallow knowledge is a limited understanding of the material whereas deep knowledge not only means that students know more about the subject but also see their knowledge as interconnected parts of a whole. This enables them to apply their knowledge to different contexts, talk about it in different ways and understand how the parts influence the whole. Deep knowledge is developed through the provision of examples that students are asked to compare and getting them to think about the deep structure of problems.

Novice and Expert thinking

Willingham (2009) distinguishes between novices and experts. The way that novices think about a subject is very different to the way experts in the field think. It is important to acknowledge that not only do students know less than experts but what they know is organised differently in their memory. The difference in how novices and experts approach problems can be summarised in Table 1.

Table 1: Comparison of novice and expert thinking (Adapted from Willingham, 2009)

Novice thinkers	Expert thinkers
When asked to solve a problem they jump in and try to solve it straight away.	When asked to solve a problem they take time to ensure that it is clearly defined. They make a conscious effort to gather more information before solving the problem.
• Focus on understanding the surface structure of a problem and relating it to what they already know. • Not able to see abstract, functional relationships between the problem they are encountering and other problems that they have experienced.	• Have abstract representations of problems and situations in their long-term memory. • Their understanding of the deep abstract structure of problems enables them to think functionally and transfer their knowledge to new situations.
• Need to consciously think about procedures as they have not yet become routine. • Must focus on the method and the solving of the problem simultaneously	• Have practised procedures to such an extent that they have become routine and this frees up space in their working memory. • Make use of this extra space in working memory to talk to themselves about the problem, generate hypotheses, test their understanding and think through the implications of possible solutions in progress.
Solutions will focus on solving the individual incident that has occurred.	Solutions are more likely to address root causes as experts know the type of problem.

In answer to the question, "How can we get students to think like experts?" Willingham (2009) states that we can't. The only path to expertise is practice. We need to provide students with practice opportunities to develop their knowledge and the abstractions

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that they need to develop an understanding of the deep structure of problems. However, we must not expect them to think like experts. This means that our focus needs to be on helping students to understand knowledge and the process followed to create knowledge in a discipline, rather than creating the knowledge itself.

Teaching thinking skills

A review of the other sources consulted shows support for the principles set out by Willingham (2009). Bellaera (2017) and Adam (1991) both investigate whether thinking skills should be taught as a separate subject in the curriculum or as part of a subject. Teaching thinking skills in isolation has been found to be ineffective as students lack the ability to transfer the knowledge to subjects and require background knowledge to think. However, students need to be taught the principles and processes of thinking along with the direct instruction of their application. Students are not able to develop critical thinking purely by interacting and learning with the subject matter.

An analysis of the methods and techniques suggested to teach critical thinking (Costa, 1991; Narode, 1987 and Walker Center for Teaching and Learning, 2018), shows that each method is aimed at addressing one or more of the following:

- Ways of improving the capacity of working memory, such as expressing thoughts aloud, recording thoughts and steps towards a solution and breaking complex ideas into manageable components (Narode, 1987).
- Ways to develop deep structure, such as defining and understanding and developing procedures to practice critical thinking skills, such as analysis, synthesis, making decisions, questioning assumptions, examining point of view and testing for relevance and accuracy. (Bellaera, 2017; Center for Critical Thinking, 1996; Costa, 1991; Walker Center for Teaching and Learning, 2018). These techniques help students move from novices to experts by explicitly teaching and encouraging the deliberate use of the thinking strategies used by experts.
- Improving the effectiveness of working memory by developing metacognition through the teaching of thinking about thinking. This makes thinking procedures automatic and ensures that students develop an awareness of the deep structure of problems. When faced with a new problem, students can solve it by recognising its deep structure and apply the thinking procedures that they have already learnt (Costa, 1991; Branigan & Kanevski, 2018).

Methods to teach analysis

In reviewing the suggested methods for teaching critical thinking, it was found that different methods serve different purposes by emphasising different aspects of critical thinking, such as problem-solving and propose different methods for addressing the three points mentioned above. The method of "Instrumental Enrichment" suggested by Link (1991) was selected as being the most suitable for the teaching of the analysis of the population pyramid.

Instrumental Enrichment was chosen because of its focus on the process of learning rather than specific skills and subject matter and because it specifically addresses the thinking process required for analysis. The Instrumental Enrichment

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programme defines analytic perception as, "the ability to analyse component parts to find out how they relate to each other and the overall character of the whole they comprise" (Link, 1991, p. 9). The process of Instrumental Enrichment comprises three steps:

1. Gathering the information needed

This involves gathering the information needed to solve a problem using the environment and the senses. Students need an understanding of how a population pyramid is structured and specific information about the country and the historical events that influenced the demographic composition of its population to analyse a population pyramid. Students need to read questions carefully to determine what information they need to gather when analysing a pyramid.

2. Using the gathered information

This step requires the most time and was the focus of the lessons to teach the analysis of the pyramid. The following steps need to be followed:

2.1 Define the problem.
2.2 Decide which information is needed to solve the problem.
2.3 Ensure that there is a good picture in the mind of what must be looked for and done.
2.4 Make a plan that will include all the steps to reach the goal.
2.5 Keep in mind the various pieces of information that are needed.
2.6 Look for the relationship by which separate objects, events and experiences can be tied together.
2.7 Compare objects and experiences to others to see what is similar and what is different.
2.8 Find the class or set to which the new object or experience belongs.
2.9 Thinking about different possibilities and figure out what would happen if one the other is chosen.
2.10 Use logic to prove things and defend an opinion.

3. Expressing the solution to a problem using clear and precise language.

Research question

After conducting the literature study, the following research question was formulated: How might Instrumental Enrichment improve Grade 7 girls' ability to analyse the population pyramid?

Implementation of the research plan

To implement the research plan, four classes of Grade 7 students were taught the material. The marks of all the classes were collected and analysed and in-depth qualitative analysis was carried out on the assessments of one of the classes. This class was randomly selected.

Teach population concepts as background information to the population pyramid

The concepts of population growth, population change, and demographics were introduced and taught. Using questioning, students were guided to think about the characteristics of specific groups within the population and their unique needs. Questions such as, "What information is needed to address the needs of babies, children, young adults and the elderly within a population?" were used to introduce and explain the population concepts of birth rate, death rate and life expectancy.

Use the existing teaching method to explain how to use the population pyramid

This method consists of the following:

- Introduce and explain the population pyramid

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The concepts of birth rate, death rate and life expectancy were explained to students. The population pyramid was introduced, and students were shown how to use it to determine the birth rate, death rate and life expectancy of a country. The video clip "Population pyramids: powerful predictors of the future" by Kim Preshoff (2015) a Ted-Ed lesson available from: https://www.youtube.com/watch?v=RLmKfXwWQtE was used to teach these concepts. Students were given the population pyramids of Rwanda and Canada and they labelled where the birth rate, death rate and life expectancy could be found on each pyramid. They then described the birth rate, death rate and life expectancy of Rwanda and Canada making the correct reference to the population pyramids.

- Explain how war, conflict and disease affect the birth rate
  The impact of war and the subsequent baby boom on the birth and death rates of a country were explained. The population pyramid of the United States was used as an example. Students completed questions analysing this impact on the pyramid. The impact of diseases, particularly AIDS, on the death and birth rate was explained but not demonstrated using a population pyramid.

- Conduct baseline assessment
  Students completed an assessment that required them to analyse the population pyramids of France and Zimbabwe and to identify the impact of World War 2 on the population of France and AIDS on the population of Zimbabwe (Table 2).

Students were required to record the thought process that they used to answer three of the questions. This information was used to gain an understanding of their ability to analyse and think systematically. If students were unable to reflect on their learning by answering the questions, it would indicate that they are not able to systematically work through a problem and are instead solving a problem by only relying on its surface elements. This ability to reflect would be reevaluated in the final assessment to see if intentionally teaching students to analyse improved their ability to reflect.

Use Instrumental Enrichment to teach analysis

Adapting the method

The method of instrumental enrichment suggested by Link (1991) was adapted to suit the analytical skills required to analyse a population pyramid. It was decided to only make use of Step 2, "Using the information we have gathered" because Step 1, "Gathering the information that we need" can be combined with "Defining the problem" and "Deciding which information is needed to solve the problem" that are part things and defend your opinion", the last step in Step 2. of Step 2. Step 3, "Expressing the solution to a problem" is included in "Use logic to prove things and defend your opinion", the last step in Step 2.

The following steps were followed to analyse the pyramid, as shown in Table 3.

1. Define the problem
2. Decide which information is needed to solve the problem.
3. Make a plan that will include all the steps to reach the goalkeeping in mind the various pieces of information that are needed
4. Use logic to prove solutions and substantiate opinions.

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Teaching the method

The method was taught using the following steps:

The steps of the method were explained to the students and two of the questions in the baseline assessment were used to demonstrate how these steps could be used to answer them. This is illustrated in Table 3. A visual illustration of the answer is given for the population pyramid of Zimbabwe in Figure 4 below: The population pyramids of France, Zimbabwe, Italy and Lesotho were analysed. Two of these pyramids were used in the baseline assessment, so were familiar to students. This allowed them to practice the method with pyramids that were familiar to them. They were asked to determine:

- the birth rate and whether the country had an increasing or decreasing birth rate;
- the death rate/life expectancy and whether the country had an increasing or decreasing death rate/life expectancy;
- the impact of AIDS (Zimbabwe and Lesotho);
- the impact of World War 2 (France and Italy).

1. The steps of the method were explained and the questions that needed to be asked to guide students at each step of the analysis process were provided. Students would not have been able to generate their questions as they had very little background knowledge of population pyramids and the method of Instrumental Enrichment was new to them.

2. Once the four pyramids had been analysed individually, specific questions were asked to assist students in comparing them. Students used the conclusions that they had drawn as a basis for studying the impact of economic status and family beliefs on the birth and death rates of a country which is the next section in the study of population geography.

Table 4 is an example of how the method

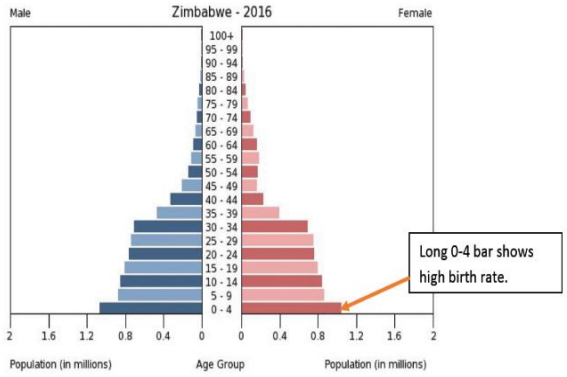

Figure 4: Population pyramid of Zimbabwe (After: Indexmundi, 2019c)

was used to analyse the impact of World War 2 on the population of France. A visual illustration of the answer is given for the population pyramid of France in Figure 5.

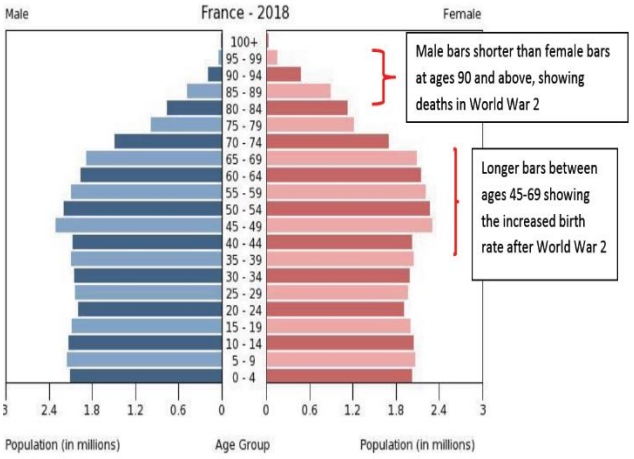

Figure 5: Population pyramid of France (After: Indexmundi, 2019b

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Table 2: Baseline assessment

Note: Questions requiring students to reflect on their thinking are not awarded a mark and do not form part of the assessment. Their purpose is to provide insight into the thought processes of students when answering the questions.		
1.	France has a low birth rate, and Zimbabwe has a high birth rate. How do the population pyramids show this?	(2)
1.1	Describe the steps that you took to work out the answer to question 1.	
2.	Does Zimbabwe have a high or low life expectancy? Give a reason for your answer by referring to the population pyramid.	(2)
3.	There are many deaths in Zimbabwe from AIDS. Which gender experiences the most deaths from AIDS? Explain your answer by referring to the population pyramid.	(2)
3.1	Describe the steps that you took to work out the answer to question 3.	
4.	How can the effects of the death rate in World War 2 be seen on the population pyramid of France? Note: World War 2 was fought from 1939-1945	(2)
5.	Why was there an increase in the birth rate of France in the 1950s and 1960s? Explain how this increase can be seen on the population pyramid?	(2)
5.1	Describe the steps that you took to work out the answer to question 5.	
6.	In the past 15 years, France has introduced policies to increase the birth rate. Have these policies had an effect? Explain your answer by referring to the population pyramid.	(2)
TOTAL		**12**

Table 3: An explanation of instrumental enrichment using a question from the baseline assessment

France has a low birth rate, and Zimbabwe has a high birth rate. How do the population pyramids show this?

Define the problem:

How does the population pyramid of Zimbabwe show that it has a high birth rate and the population pyramid of France show that it has a lower birth rate?

Decide what information is needed to solve the problem

The birth rate relates to the number of babies born so is shown by the 0-4 bar of the population pyramid. If this bar is long the birth rate is high, if it is short, the birth rate is low.

Make a plan that will include all the steps to reach the goal that keeps in mind the pieces of information that are needed.

To answer the question, look at the 0-4 bar of the population pyramids of France and Zimbabwe. Background information suggests that the 0-4 bar of France will be low, and the 0-4 bar of Zimbabwe will be high.

Use logic to prove your answer.

France has a low birth rate because the bar 0-4 are short and Zimbabwe has a high birth rate because the bar 0-4 is long.

Concluding assessment

Once the analysis of the pyramid had been undertaken, the following concluding assessment (Table 5) was administered. The questions were similar to the ones asked in the baseline assessment, but the assessment was set on the population pyramids of Swaziland and Japan. Students were asked to describe the thought process that they used to answer three of the questions. This would show if there had been a development in the way students approach questions and their understanding of their thought processes.

Data gathering methods:

The following methods were used to collect data:

- Own observations.
- Baseline assessment and students' reflection on thinking.
- Concluding assessment and students' reflection on thinking.

Analysis and interpretation of data

Observations:

The following observations were made during the initial teaching of the population pyramid to students.

- One class did the initial analysis of the pyramid easily but still did not do well in the baseline assessment.
- Students struggle to identify the death rate and life expectancy on the pyramid. They thought longer bars at the top of the pyramid meant a high death rate as longer bars showed that more people have died. This was explained in terms of addition and subtraction – a
- high birth rate means that more people are added, and a high death rate means more people are subtracted, so the bars at the top are shorter.
- Students related the life expectancy to the birth rate by saying life expectancy was high because the bars at the top are longer than those at the bottom.
- Some students used the numbers in the population given at the bottom of the population pyramid to compare the birth rates of different countries, even after an explanation was given. It was explained that they need to relate the length of bars to the ones above to see the number of births as a proportion of the population.
- Students have difficulty finding the correct age range on a population pyramid using dates. For example, the current age of people born after World War 2.
- Students confuse the concepts of birth and death rates by saying children die in war due to bombing, so the birth rate decreases.
- When it was explained that people who died in World War 2 are approximately 91 and asked which bars on the pyramid must be looked at, the students said 55.
- Students wanted to use the 0-13 bars on the pyramid to work out the birth rate after World War 2.
- Working through the questions provided for each population pyramid provided a useful basis for student-initiated group discussions and guided them in their observations of the population pyramid. The questions also provided a useful tool for the author to engage the students in discussion to correct their thinking or guide them to the correct conclusion.

Analysis of data

A comparison of the baseline and formal assessment results showed an improvement in the overall understanding of the analysis of the population pyramid. The grade average improved from 48% in the baseline assessment to 60% in the concluding

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assessment. It is not certain whether this is due to repeated exposure to the population pyramid or the use of Instrumental Enrichment. However, repeated exposure to examples meets Willingham's (2009) criteria for the development of deep knowledge as it helps students to progress from novice to expert thinking by requiring them to think about the deep structure of problems. A more detailed analysis of the two assessments based on the answers given by one class of 19 students shows the following:

Birth rate

There was an improved understanding of the birth rate on the population pyramid. All the students were able to correctly identify the birth rate in the follow-up assessment compared to 12 in the baseline assessment. Four students did not explain their reasoning correctly in the baseline assessment. Of these, three students were still unable to correctly explain their reasoning in the follow-up assessment. One student could explain her reasoning in the baseline assessment but did not in the follow-up assessment. There were seven incorrect answers in the baseline assessment and none in the follow-up assessment.

Life expectancy

All students understood life expectancy in the follow-up assessment compared to 10 in the baseline assessment. Three students were unable to explain their reasoning in the follow-up assessment compared to six in the baseline assessment. One of these was the same as the one who could not explain her reasoning in the birth rate question. The other two could explain their reasoning in the birth rate but not the life expectancy. There were three incorrect answers in the baseline assessment and none in the follow-up assessment.

Impact of AIDS

Analysing a population pyramid to identify the impact of AIDS on a population still presented difficulties for students in the follow-up assessment. Although there was an improvement, six students obtained a correct answer in the baseline assessment and there were two questions in the follow-up assessment which were answered correctly by eight and nine students respectively. However, accurately determining the age range affected by AIDS remained problematic. 16 students were unable to answer this in the baseline assessment and 12 in the follow-up assessment. Of these, nine names occurred both times, seven students got the answer incorrect in the baseline assessment and three in the follow-up assessment only.

Impact of World War 2 on the death rate

There was a significant improvement in this question. No students got the full two marks in the baseline assessment with eight obtaining one out of two. In the follow-up assessment, 11 students received full marks. Three students received no marks in the follow-up assessment compared to 11 in the baseline assessment. A comparison of the students with either zero or one out of two in both assessments shows that five did not get full marks in both assessments. 10 obtained full marks in the follow-up assessment but not in the baseline assessment and three obtained full marks in the baseline assessment but not in the follow-up assessment.

The baby boom after World War 2

There was no noticeable improvement in this question in the follow-up assessment. Five

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students got the answer correct in both assessments and they were the same students. The number of students with a mark of zero out of two increased from seven to 13 in the follow-up assessment.

Finding an increase or decrease in the birth rate over time

There was a slight improvement in this question. There were three correct answers in the baseline assessment and six in the follow-up assessment. However, the number of totally incorrect answers (zero out of two) increased from five to eight. In the baseline assessment, the students were more accurate in their interpretation of the data but in the follow-up, the assessment did not interpret the question or read the pyramid correctly. Many of them did not correctly answer the question by motivating their answer by referring to the pyramid.

Recording of thinking

There was no evidence of an improvement in the students' thought processes or ability to record their thinking in the

follow-up assessment. Apart from one or two exceptions, they did not show that they had used Instrumental Enrichment as a method when answering the questions.

Conclusions and reflections

Students do not always follow the steps of Instrumental Enrichment when answering questions. This is evidence of novice thinking as they are solving a problem by trial and error and not first stepping back and gathering the information that is available that is characteristic of expert thinking. Their approach to the following illustrates this:

- In the question on the impact of AIDS, students said that the female bars were shorter than the male bars from ages 15-49 or guessed the age range. Had they used Instrumental Enrichment, they would have applied the background knowledge that AIDS affects more females than males in the 15-49 age group to make a specific observation of the population pyramid of the exact age groups at which the female bars are shorter than the male bars.
- The second assessment showed an improvement in the students' ability to activate background knowledge by correctly identifying the age groups affected by a high death rate in World War 2, however, they were not able to activate the same background knowledge to identify the age groups affected by the baby boom.
- They were not able to make inferences from their background knowledge and observations of the population pyramid to answer questions on the increase or decrease of the birth rate. Many of them did not read the questions carefully.

Although students could not apply Instrumental Enrichment correctly, it did provide a useful tool to help them to interpret the representation of the population concepts on the pyramid. Instrumental Enrichment met Willingham's (2009) criteria for developing deep knowledge by asking the students to think about how a pyramid is structured and providing examples for the students to compare. Students' inability to apply Instrumental Enrichment independently agrees with:

- the cognitive principle stated by Willingham (2009) that students remember what they think about;
- the findings of Bellaera (2017) and Adams (1991) that students need to be explicitly taught the principles and processes of thinking along with the direct instruction of their application and

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do not develop critical thinking purely by interacting and learning with the subject matter.

During these lessons, students were thinking about the population pyramid and not Instrumental Enrichment. Instrumental Enrichment was an effective tool in teaching students about the population pyramid as it made them think about the population pyramid. However, if students are to learn to use Instrumental Enrichment independently, they need to be taught this approach in a lesson focusing exclusively on Instrumental Enrichment that requires them to think about their thought processes and the steps they follow when engaging with the population pyramid. This would need to follow on from the teaching of the population pyramid and provide opportunities to think about the critical thinking processes independently of their knowledge.

As Instrumental Enrichment was implemented as part of an action research project, it was necessary to teach the population pyramid using the existing method to obtain a baseline assessment. However, Instrumental Enrichment needs to be taught alongside the population pyramid and students need to analyse several population pyramids over a period of time instead of all at once. The following approach is suggested:

1. The concepts of birth and death rates are taught. Instrumental Enrichment is explained, and direct guidance provided to the students to use the steps in Instrumental Enrichment to analyse the population pyramid to find the birth and death rates.
2. The impact of war on the population is taught. Students are given a different population pyramid and direct guidance is used to determine the impact of World War 2 (1939-1945) on the population of a country using Instrumental Enrichment. Students are reminded of the steps required to find the birth and death rate and use Instrumental Enrichment to find these on the population pyramid. This focus during this activity would be on encouraging students to think about their thought processes and how they are using Instrumental Enrichment to find the answer, rather than on the answer itself. A second population pyramid will be given, and students will be required to determine the impact of World War 2 (1939-1945) on the population of a country using Instrument Enrichment, without guidance.
3. The same process is followed to teach the impact of AIDS on a population.
4. Students continue to practice thinking about Instrumental Enrichment and applying the steps to the analysis of population pyramids. Eventually, they should be able to use Instrumental Enrichment to determine for themselves how they need to analyse a population pyramid when given a new type of question such as determining the age group at which the death rate decreased.

The action research project showed that is it effective to teach students to analyse a population pyramid by giving them tools that help them to guide their thinking and focus on what they need to think about. However, the principles and processes of critical thinking need to be taught separately from the material if students are to apply them independently. However, as factual knowledge precedes thinking and critical thinking processes are intertwined with knowledge in the long-term memory (Willingham 2009), the principles and processes of critical thinking need to be

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taught using the population pyramid as a specific context. Instrumental Enrichment proved to be an effective tool to improve Grade 7 girls' ability to analyse the population pyramid.

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