Some Thoughts on Hypothesis Testing and Higher Order Thinking in "O" Level Geography Teaching

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Introduction

"The shrewd guess, the fertile hypothesis, the courageous leap to a tentative conclusion – these are the most valuable coin of the thinker at work." So stated Jerome Bruner in 1960, applicable then as applicable now, particularly when it comes to higher-order thinking skills in school geography. Hypothesising and hypothesis testing are processes which automatically actuate the brain onto levels of thinking well above those requiring mere recall and comprehension. On a recent in-service course for teachers of geography, participants gave the impression that the formulation and testing of hypotheses are as yet little used in Singaporean secondary schools. One reason would seem to be a belief that in order to use hypothesising, teachers must have more than a basic understanding of statistical procedures. Indeed many teachers seem to have a built-in aversion to anything that remotely appears to be mathematical. All nevertheless recognise, that in a world in which geographical data increases enormously every day, techniques have to be adopted in our lessons which help simplify or rationalise the factual complexity of the world around us.

There has been as a consequence, a growing emphasis on the interpretation of statistical data in both geography texts and examinations along with a realisation that sooner or later geography teachers must become conversant with at least some of the concepts involved. The current trend in public examinations is towards this type of exercise. However, it is not the purpose of this short article to discuss the rationale for a greater statistical understanding by geography teachers, an observation now generally accepted, but rather to demonstrate that even in their simplest form the methodologies are not too complex, are well within the scope of every teacher and more importantly, provide an excellent strategy for stimulating higher order thinking within our pupils. But first, some statistical revision or explanation will be necessary for teachers who have not yet come to grips with statistical methodology.

Some Understanding Of Statistical Concepts

A hypothesis is defined (Concise Oxford Dictionary) as "a supposition made as a starting point for further investigation from known facts". From a geographer's point of view, "it is Bruner's "shrewd guess" or that inquisitive hunch one might have suggesting a linkage between phenomena or events. One might presuppose that two sets of occurences or variables are connected with one another in some way. The annual rainfall totals of places might, for example be influenced by their altitude, or perhaps national death rate might be related to the general wealth of a country. The average temperature of a place might have altered over the years with urban development or the flow of traffic might be related to time of day. These are fairly straightforward relationships which have to be stated in a scientifically acceptable way if some form of objective analysis is to follow. In a nutshell, the hypothesis has to be formulated and the relevant data required to test that hypothesis has then to be collected. Most hypotheses tend to begin with the word "that" eg "that ... rainfall totals increase with height", "that ... death rates are influenced by national wealth" and "that ... the amount of traffic on a road is related to the time of day". It is accepted geographical procedure to state the hypothesis in a negative manner, the Null Hypothesis (abbreviated H). This states that no relationship exists between the two variables but having stated it, one then goes on to try and disprove it, an approach likened to a judicial system which assumes that people are innocent until proved guilty.

Thus, the null hypotheses for the above examples might be "that no relationship exists between altitude and rainfall totals", "that no relationship exists between Gross Domestic Product (GNP) and death rates" and "that no relationship exists between amounts of traffic flow and time of day." Once the null hypothesis has been stated the relevant data has to be collected to test its validity. Information can be collected first-hand from fieldwork or from secondary sources using data that someone else has already assembled. Singapore teachers have the advantage that much statistical data is already available for them in the various published yearbooks of statistics. Assuming that the relevant data has been collected from either means, a suitable statistical test has then to be applied.

One such statistical test with a formula simple enough to be used in secondary schools is the Spearman's Rank Correlation Test (see Append 1 for a worked example). It is a non-parametric test and uses the "ranking" or ordering of the data rather than the data itself. For practical purposes this means that the arithmetic involved is quick and easy to calculate. Data for each variable are listed side by side and then ranked from the highest to the lowest position. The differences between the two ranks are squared and then added. By using the given formula a correlation coefficient (Rs) is calculated, indicating the strength or degree of correlation existing between the two variables. (Note: For those who might have forgotten about correlation coefficients, they are based on a scale of 1 to 0, with zero equalling 'no correlation' and '1' meaning 'perfect correlation'. In-between measures indicate some correlation, weak or strong depending on how near they are to the extremities of the scale. The correlation can be negative or positive). The calculation is best undertaken by setting out the data in tabular form (See Append 1). Once calculated, the correlation coefficient is examined for "significance" using Critical Value tables (see Append 1).

Testing for significance is like asking the question whether the calculated coefficient actually signifies anything or not. It is done by employing tables based on probability, or the odds for and againstyour calculation showing something that has been arrived at purely by chance. The tables take into account the number of pairs of data involved (statistically known as the Degrees of Freedom). The more data you use the greater the likelihood of the coefficient being significant. The Critical Value Table indicates to you whether the original null hypothesis can be accepted or rejected. If the null hypothesis is rejected, then the alternative hypothesis (H,) must be accepted, i.e., that rainfall and altitude are related; that death rates and GDP are related, and that traffic flows are influenced by time of day. Whether or not these are causal relationships is a matter which might be discussed. The whole process is summarised stage by stage in Figure 1.

Hypothesis Testing And Higher Order Thinking

So what of hypothesis testing and higher-order thinking once you have come to grips with Spearman and its concepts? Of course you cannot see cognitive processes in operation but pupil responses indicate the thought levels at work. Lower-order thinking reveals itself in the teaching situation for example, when a pupil is asked a question and answers by repeating only information that has been taught previously or uses information which is common knowledge. Nothing new is added to the information and the answer is presented in the same format as originally encountered.

Conversely, higher-order thinking is apparent when an individual is able to organise an answer by adding to the original information and by presenting it in a different manner or perspective from that in which it was previously experienced. The pupil is able to change and add to this information by making contrasts or comparisons, and by demonstrating abilities to analyse, synthesize, summarise and evaluate in order to answer. The capacity to show proficiency in these abilities is one of the hallmarks of higher order-thinking. From a teacher's point of view, it is worth remembering that lower-order thinking, as reflected by lower-order answers, may be responses more related to lower-order questioning than an indication of mediocre cognitive ability. Low level qustioning naturally generates only low-level answers and low level-answers are the product of low-level thinking. It is unfortunate that low-level questions are the ones that come most easily. As teachers, we have the power to raise the level of pupil thinking by raising the level of the questions we ask. In the same way, teachers setting lower-order exercises will generate little thinking by way of return. Given enough practice or exposure to either lower-order questions and lower order-exercises, it follows that lower-order thinking becomes the norm. Indeed, once this method of thinking has been accepted by pupils as all that is required of them, it becomes increasingly more difficult for teachers to raise this level.

FIGURE 1: HYPOTHESIS TESTING AND TYPES OF THINKING

Stages	Hypothesis Testing	Some Types of **Thinking** Involved.
Stage 1	Have "Hunch"	Perceiving; Comtemplating; Considering; Assuming; Relating; Comparing; Contrasting; Observing; Deducing; Discerning; Detecting; Assessing.
Stage 2	Develop Hypothesis	Composing; Combining; Deciding; Reasoning; Formulating; Modifying; Inferring; Expressing.
Stage 3	Plan Procedure	Designing; Planning; Arranging; Organising; Systematising; Proposing; Rationlising.
Stage 4	Collect Data	Determining; Selecting; Classifying; Operationalising.
Stage 5	Test Data	Applying; Solving; Analysing; Calculating; Interpreting; Appraising.
Stage 6	Draw Conclusions	Assessing: Synthesising: Concluding: Proposing: Deducing: Validating: Appraising: Judging: Generalising.

The whole procedure involved in hypothesising and hypothesis testing is a higher-order exercise which stimulates and encourages higher-order thinking. Abstract concepts are acquired as pupils are encouraged to formulate the hypothesis; plan the programme for obtaining the statistics (this is particularly so when fieldworkis involved); apply the relevant technique; analyse the results; synthesise .the material; make inferences from the results; draw conclusions; evaluate and perhaps go on to make predictions. The teacher will have to plan the exercise very carefully and guide the pupils through each stage. Thought will have to be given to the questions posed but higher-order thinking will certainly be stimulated. Column 3 of Figure 1 indicates some of the types of thinking that you will encourage. Once a teacher is Happy with utilising a technique such as Spearman, the questions will come automatically. To this end, a worked example has been incorporated as an appendix to this short article for those teachers who are unfamiliar with correlations of this type but wish to make a start. The example takes the case of Singapore, and relates infant mortality rates to numbers of medical staff. The exercise is quite straight forward and should provide the minimum of difficulties. For a class to successfully complete the various stages, pupils will have to utilise the more advanced thinking skills.

Conclusion

In the hands of a teacher willing to try this type of work, even those with little or no statistical ability, hypothesis testing will prove to be an approach which is interesting and pedagogically satisfying. Even more important, it is an approach which stimulates and encourages pupils to raise their thoughts onto planes of higher-order thinking.

APPENDIX **1** THE WORKED EXAMPLE

1. STAGE **1:** "THE HUNCH"

If the number of medical staff in a country increases, then this will be reflected in the improved health of the country and this might be demonstrated in a decrease of the infant mortality rate.

2. STAGE **2:** THE HYPOTHESES

(a) The null hypothesis ... "that no correlation exists between the number of medical personnel in Singapore and the infant mortality rate of Singapore".

(b) The alternative hypothesis ... "that a correlation does exist between the numbers of medical personnel and infant mortality rate in Singapore." It is assumed that as the numbers of doctors and nurses increase then the infant mortality rate should decrease.

3. STAGE 3: PLAN THE PROCEDURES

In this particular example, statistics which have already been collected are going to be used. Where fieldwork is involved, careful thought will have to be given to this stage.

4. STAGE 4: COLLECTING THE DATA

Data for this example is to be found in the Singapore yearbooks of statistics from which the following table has been compiled.

INFANT MORTALITY RATES AND MEDICAL PERSONNEL IN SINGAPORE

YEAR	RMP	IMR	YEAR	RMP	IMR
1971	590	20.1	1981	914	10.7
1973	706	20.3	1983	1047	9.4
1975	775	13.9	1985	1214	9.3
1977	752	12.4	1987	1420	7.4
1979	806	13.2	1989	1720	6.6

IMR : Infant mortality rate [per thousand live births]
RMP : Registered medical personnel [Government Service]

Source: Singapore year books of statistics.

5. STAGE 5: CALCULATING THE CORRELATION COEFFICIENT OF THE DATA USING SPEARMAN'S RANK CORRELATION TEST

(a) Tabulate the data as follows:–

YEAR	DATA SET X RMP	RANK DATA X	DATA SET Y IMR	RANK DATA Y	DIFFERENCE BETWEEN RANK X AND RANK Y	d^2
1971	590	10	20.1	2	8	64
1973	706	9	20.3	1	8	64
1975	775	7	13.9	3	4	16
1977	752	8	12.4	5	3	9
1979	806	6	13.2	4	2	4
1981	914	5	10.7	6	-1	1
1983	1047	4	9.4	7	-3	9
1985	1214	3	9.3	8	-5	25
1987	1420	2	7.4	9	-7	49
1989	1720	1	6.6	10	-9	81

[The sum of the different between the ranks squared] $Cd^2 = 322$

(b) Apply the Spearman's Rank formula of:

$$R_s = 1 - \frac{[6 \sum d^2]}{[n^3 - n]}$$

where : – R = the Spearman Correlation Coefficient

C = the sum of.

d^2 = the difference between Rank x and Rank y, squared.

n = number of pairs

Thus : – $R_s = 1 - \frac{[6 \times 322]}{[1000 - 10]}$

$\underline{R_s = -0.95}$

(c) This is a high degree of negative correlation so it can be concluded that the two variables appear to be very strongly related. As one goes up, the other goes down. But given that we have only taken 10 pairs of data, what is the possibility that these are purely random and do not reflect the real situation at all? We have to test for significance.

6. STAGE 5a: TESTING FOR SIGNIFICANCE

You may feel that testing for significance is too advanced for some pupils. It is certainly required in an "A" Level situation but is well within the scope of brighter "O" Level pupils.

(a) Refer to the Critical Value Tables of the Spearman's Rank Correlation Coefficient in a statistical tables text. A short extract from such tables has been added here.

Degrees of Freedom	Significance Level		
	0.1	0.05	0.01
4	1.000		
5	0.900	1.000	
6	0.829	0.886	1.000
7	0.714	0.786	0.929
8	0.643	0.738	0.881
9	0.600	0.683	0.833
10	0.564	0.648	0.794
11	0.523	0.623	0.818
12	0.497	0.591	0.780
13	0.475	0.566	0.745
14	0.457	0.545	0.716
15	0.441	0.525	0.689

(b) Interpret the column of "Degrees of Freedom" as meaning the number of pairs of data that you have taken, i.e., 10.

(c) The values in the table are known as critical values and have been calculated according to probabilities. Significance levels relate to probabilities of 10 in 100 (0.1), 5 in 100 (0.05) and 1 in 100 (0.01). Your calculated correlation coefficient is related to the table according to the degrees of freedom. In all cases the instruction is: REJECT THE NULL HYPOTHESIS (H) IF YOUR CALCULATED R IS GREATER THAN THE CHOSEN SIGNIFICANCE LEVEL.

STAGE 6: RE-EXAMINE THE ORIGINAL NULL HYPOTHESIS AND DRAW CONCLUSIONS

R was calculated as -0.95. With 10 degrees of freedom (number of pairs) the table value at the 0.01 Significance is 0.794. Our calculated R is much higher than this [Note: ignore the minus sign]. Thus we can reject the null hypothesis "that no correlation exists between the number of medical personnel in Singapore and the infant mortality rate in Singapore". We accept the alternative that a correlation does exist between the two and that during the 1971 to 1989 period, there was a strong negative correlation between the number of available medical personnel and the infant mortality rate, and that as the numbers of doctors and nurses went up, the infant mortality rate went down. We can state this with the certainty that there is less than a 1 in 100 possibility that our figures are unrepresentative of the real situation. The question will remain as to whether this is a causal relationship or whether other factors are involved such as a general improvement in public hygiene and living conditions, a better understanding of dietary requirements during pregnancy and so on. Questioning at this stage reveals some quite creative ideas on the part of the pupils.

References

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