Reading Graphs and Interpreting Numerical Data using the "Rubrics Strategy" Based on Bertin's Theory in Biology

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Abstract:- The teachers investigated and practiced the pedagogical problems through the "Action Research" and "Lesson Study" projects systematically in Nazarbayev Intellectual Schools (NIS), Kazakhstan. One of these projects entailed the need to develop the skills of the International School of Astana (part of NIS) students to read and interpret graphs. Within the framework of the Action Research project, four different strategies for reading the graphs and interpreting the numerical data resulted from the laboratory work of the 10th-grade students (17) in biology. The Text Structure Strategy (TSS), High-impact teaching strategies (HITS), Model Questioning as an Active Reading Strategy and the rubrics strategy based on Bertin's theory were used and analyzed. As a result of the study, the latter theory was determined to be the most effective. Based on Bertin's theory, the rubrics involves gradually teaching students the necessary knowledge to read quantitative data in three steps at three different levels and performing two diverse activities. The study revealed a notable 41% exponential surge in students' proficiency in graph analysis, progressing from simple to complex levels. Hence, the research findings are poised to serve as a valuable reference for schoolteachers and students to be commonly utilized in mathematics and sciences.

Keywords*: Quantitative Data, Qualitative Information, Graph, Rubrics, Strategy, Indicator, Interpretation*

1. Introduction

Graphing is a skill that helps predict problems and consequences and identify specific laws in science, technology, and mathematics. The most common graphs consist of opposing axes, units, intervals, numeric data, and labels. Reading graphs is a core skill for scientists (Beichner, 1994), and creating and interpreting graphs plays a critical role in science (Bowen & Roth, 1999). Therefore, varying age groups of students encounter distinct challenges while utilizing, interpreting, or constructing graphs. (Leinhardt et al., 1990). Moreover, there is a need to develop a high level of Bloom's taxonomy skills (data collection, analysis, evaluation) for identifying mutual differences and similarities in studying natural phenomena and interpreting numerical data in graphs. The study aimed to enhance students' ability for graph analysis in response to diverse experiments prevalent in biology. The following activity was planned as the research objectives: consider strategies that allow you to read graphs and determine the effectiveness of the chosen strategy.

The Text Structure Strategy (TSS) serves to decipher graphs, while the High Impact Teaching Strategy (HITS) aids in substantiating qualitative information based on quantitative data within graphs. Additionally, the Model Questioning as an Active Reading Strategy is employed to generate graphs from qualitative information within the text. Lastly, Bertin's theory is utilized in formulating a "rubrics strategy" for interpreting graphs.

The TSS (Meyer, 1975) shows that texts are based on hierarchical structure and promote information retention. This strategy consists of problem and solution, cause and effect, sequence, comparison, and description when analyzing graphs. The text structure is effectively employed to create information in science, social studies, and sport.

A worked example (HITS) provides students with a step-by-step solution to a problem or process to be performed. By providing an example of a graph reading model, the goal is to allow students to analyze graphs (Trafton & Reiser, 1993) and read extensively (Schwonke at al., 2009) while looking at the model. This allows learners to practice and review analysis skills, aiding the retention of the structure inherent in the analytical passage.

The proficiency in interpreting and analyzing graphs through text-dependent questions is prevalent (Fisher & Frey, 2012). By creating questions depending on some graphs, it is quite possible to conclude from qualitative information.

The rubrics strategy (Bertin's Theory of Graph Interpretation, 1983) consists of descriptors that allow students to read graphs. The rubrics comprises a sequential framework designed to develop both foundational and advanced skills among students. The rubric is suitable for developing the skills of reading and analyzing graphs for students of different ages.

Research question: Is it possible to develop students' skills in reading and analyzing graphs with the help of selected strategies?

Hypothesis: Reading and analyzing graphs using a rubric will be more effective than strategies for creating graphs from textual information.

Expected results: Tenth-grade students will acquire the ability to proficiently interpret and analyze graphical representations across diverse academic disciplines.

2. Methodology

Grade 10 students (nine boys and eight girls) of the International School of Astana were taken as the object of the research. In Grade 8, the main focus was on creating research variables and hypotheses in Grade 9, identifying safety, and analyzing numerical data in a table, and in Grade 10, the main focus was on creating graphs and developing reading skills in graphs. Biology was taught twice a week. The four selected strategies were implemented during the first term, followed by the identification and evaluation of their respective positive and negative impacts. Subsequently, through a comprehensive analysis of these strategies, the "rubrics strategy" was singled out.

It was determined that the main problem is forming the skills necessary for 17 students to create graphs and read them using the "rubrics strategy" (The University of Wisconsin Press, Ltd., Madison). According to the rubrics strategy, graphs at different levels are characterized by three main approaches: mathematical word problems (algorithm focus), scientific data analysis (application of scientific knowledge), and data-driven extraneous analysis.

Bertin (1983) divided the stages of reading graphs into three successive steps. In the first phase, the external determinant phase, students read the graph and identify the x- and y-axis labels, units, intervals, scale, etc. when detected. In the second internal defining stage, the student recognizes the the components and visual layout of the graphs. In the final stage, the learners distinguish the distinctiveness of the drawing and determine its features.

Bertin (1983) divided his graph description questions into three levels with their characteristics: (1) the basic level, which is the part of information that students can identify from the graph, (2) the intermediate level, which allows students to observe common patterns between groups of elements in the graph and gather information, (Bertin, 2001), and (3) the general level is used to develop basic knowledge and experience.

"RUBRICS CRITERIA"		
Simple level indicators	**Intermediate indicators**	**General level indicators**

Reading data	*Identifying relationships between data*	*Data-driven external learning/analysis*
a. Determining/reading the "*x-y* coordinates" of the drawing point; b. Finding the point/values with given "*x-y* coordinates"; c. Selecting the appropriate *X* (or *Y*) value for the *Y* (or *X*) value in the given chart; d. Reading point value using axis and label; e. Knowing that *x* is the horizontal axis and *y* is vertical in the "*x*, *y*" coordinate pair.	a. Making (qualitative) comparisons between data points (i.e. more, higher, lower, less, etc.); b. Calculating the relative (numerical) difference between data points; c. Describing the relationship between the data shown in the graph; d. Determining the relationship between linear curves in a graph; e. Choosing a chart that can transform data.	a. Showing the deviation in the content of the graph that affects the interpretation; b. Identifying concepts of thematic content that affect interpretation; c. Determining scientific information about the content of the graph that affects the interpretation; d. Determining the correlation between the graph's content and personal experiences, thereby influencing its interpretation. e. Linking with a built-in theory that affects interpretation.

3. Result

When using the "Text Structure Strategy", students were guided to develop qualitative concepts by reading and using graphs. For example, during the study of the factors influencing the process of photosynthesis, the problem/cause was determined; the sequence of the problem, the consequences for nature and humanity, a comparison of studies, and a solution/description were given. Indeed, the primary limitation of this strategy lies in its deficiency in conducting quantitative data analysis.

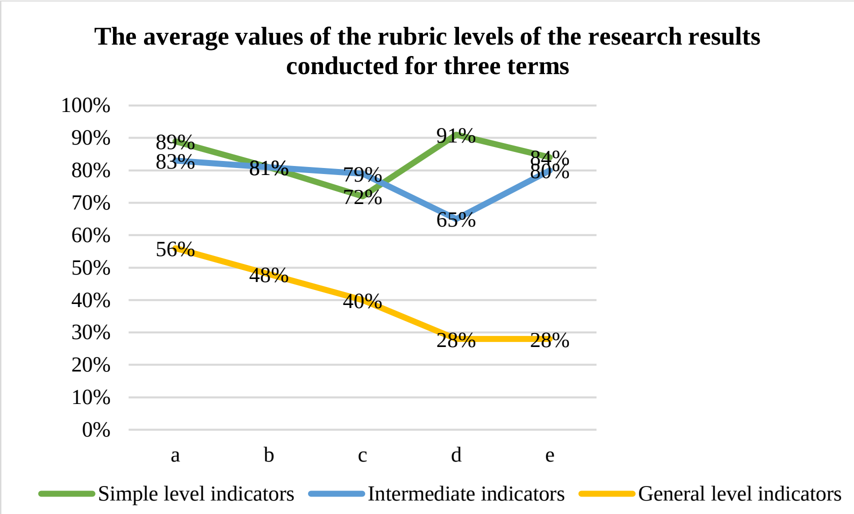
In the HITS strategy, by providing a model version of the graph description, students are taught to work on a basic rule/guideline basis during the analysis phase but are limited to their ideas, and logical and critical thinking.

Although the ability to read graphs increases when answering text-dependent questions, the teacher has to work hard for each study. This is because the list of text-dependent questions is constantly changing according to the topic. Creating consistent guidelines for interpreting graphs is challenging or not feasible. Hence, the concern regarding the level and quality of the questions stems from potential instances of "hidden hints," implicit "directions," or even answers embedded within the question structure. Thus, the strategies described above were considered ineffective.

In addition to demonstration, modeling, and practical lessons, a total of 7 laboratory works were conducted and monitored in Grade 10 from the 1st through 3rd terms. The quantitative data acquired from each laboratory experiment was aggregated into a table, and subsequently used to generate linear graphs. Subsequently, leveraging Bertin’s theory for graph interpretation, the analysis of quantitative data through "rubric questions" facilitated the transformation of qualitative information into research analysis, thereby enabling the evaluation of research conclusions. Each of the students' findings/conclusions was analyzed and evaluated using a rubric. Then the "rubric" served as a guide and evaluation criteria to help write the conclusion. The research results are presented in Table 1 below.

Results of reading and interpreting graphs using Bertin's rubrics according to the study carried out between the 1st and 3rd terms

	Laboratory works							
Rubrics	No.1	No.2	No.3	No.4	No.5	No.6	No.7	
Simple level indicators								**Average**
a	71%	77%	88%	94%	94%	100%	100%	89%
b	65%	76%	71%	82%	76%	94%	100%	81%
c	76%	70%	82%	94%	88%	94%	100%	72%
d	70%	83%	88%	94%	100%	100%	100%	91%
e	65%	71%	75%	83%	94%	100%	100%	84%
Intermediate indicators								**Average**
a	53%	71%	88%	82%	94%	94%	100%	83%
b	59%	65%	76%	82%	94%	94%	100%	81%
c	53%	70%	65%	88%	82%	94%	100%	79%
d	47%	53%	65%	59%	71%	76%	82%	65%
e	59%	71%	82%	76%	88%	88%	94%	80%
General level indicators								**Average**
a	41%	47%	59%	65%	53%	59%	65%	56%
b	35%	47%	41%	35%	53%	59%	65%	48%
c	35%	29%	35%	41%	47%	41%	53%	40%
d	29%	24%	18%	35%	29%	35%	29%	28%
e	29%	29%	24%	18%	29%	35%	29%	28%



4. Conclusion

Analyzing the results of the research, among the four different strategies according to the research task, the "rubrics strategy" based on Bertin's theory was determined to be the most effective. In the rubrics strategy, the list of questions served two different functions: a guide to generating qualitative information (meaning-making) while reading the chart, and assessment descriptors. For each question, each student developed three levels of graph interpretation skills, from simple to complex.

The exponential progression of students' skills aligned with the descriptors at every level suggests the complete fulfillment of the research objective. Based on the growth rate of 35% at the elementary level, 53% at the intermediate level, and 36% at the general level, it is reasonable to infer that employing the rubric for graph description has yielded favorable outcomes. The differences between the levels (simple and intermediate) are equal to the Student's t-test coefficient, which is 1.8, and the standard deviations equal to 0.5 support the null hypothesis. This indicates that there are no differences between the values of the two indicators.

On average, the highest indicator belongs to the simple level, and the lowest indicators belong to the descriptors of the general level, that is, the students, based on their experience when reading graphs, had difficulty in establishing the connection between various scientific and integrated laws in the content of the graphs. Hence, a new area of professional development was defined.

The Action Research project aimed to have a positive result, to share the experience in the school community at city/regional level seminars, and to create a guide that would help students of any grade to read graphs and interpret data based on Bertin's rubrics strategy.

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