

Research Review: The SOLO Taxonomy (Structure of the Observed Learning Outcome) in Mathematics Education

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Abstract: The application of the SOLO Taxonomy in Mathematics Education was analyzed by using content analysis and bibliometric method, combined with the knowledge map drawn by CiteSpace software. Based on this, the following suggestions were put forward for the next research hotspot of The SOLO Taxonomy: Using theory to guide layered teaching; Constructing a formative teaching evaluation model; Developing course resources.

Keywords: The SOLO Taxonomy; Mathematics Education; Knowledge Graph

1. Introduction

In 1982, the concept of "The SOLO Taxonomy" was introduced by Australian educational psychologist John Biggs and his colleague Collis. They believed that by examining students' cognitive development in terms of their operational thinking mode, it is possible to differentiate their answer level based on four aspects: ability, thinking operation, consistency and convergence, and response structure. This taxonomy identifies five levels of thinking – initial level, single point structure, multi-point structure, association structure, and abstract extension structure – based on the complexity and hierarchical characteristics of individual responses. Through content analysis and bibliometric method combined with CiteSpace software's knowledge map visualization tool, this study examines the application research literature of the SOLO Taxonomy in mathematics education to provide valuable insights for enhancing mathematics instruction.

2. Research process and results

2.1. Research Data

In December 2023, with the topic of "SOLO" including "mathematics", a search was conducted on CNKI. It was found that from 2005, with the implementation of the curriculum reform of basic education, the number of articles on the SOLO Taxonomy increased year by year and showed a trend of diversification. According to CiteSpace software, 824 literatures from 2005 to 2023 were reviewed.

2.2. Research Methods

CiteSpace was developed by Professor Chen Chaomei from Drexel University in the United States based on java language, which can present the distribution, rule and structure of scientific knowledge through visual graphics, effectively capturing the key points and turning points of research.

2.3. Research Result

2.3.1. Key words of Research

Keywords are the author's highly concise and summary of the content of the article, which can reflect the core content of the literature[1]. The co-occurrence map was drawn by selecting the keywords that appeared in the top 10% of each time slice (1 year). The color of the relationship line of the map

transitioned from dark blue to orange-red as time progressed, and the node size represented the keyword frequency.

From Figure 1, it can be seen that The SOLO Taxonomy has been increasingly applied to the mathematics education of primary and secondary schools. Combined with Table 1, high school mathematics, deep learning, cognitive level, primary school mathematics, understanding level and teaching strategy are the key words that researchers mainly focus on. It can be seen that the literature research on high school and primary school is much higher than that on middle school[2]. The SOLO Taxonomy study in junior middle school mathematics needs to be further developed.

Table 1: Collinear list of literature keywords from 2005 to 2023.

Serial Number	Frequency	Time	Keywords
1	223	2007	The SOLO Taxonomy
2	164	2016	High school mathematics
3	129	2020	Deep learning
4	113	2016	Cognitive level
5	76	2014	Elementary mathematics
6	64	2019	Understanding level
7	62	2020	Teaching strategy
8	61	2017	Junior high school mathematics
9	58	2020	Instructional design
10	34	2019	Core quality

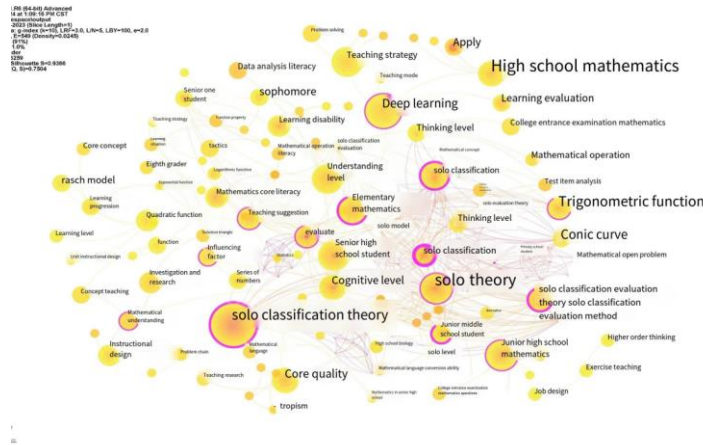


Figure 1: Cluster Graph of Literature Keywords from 2005 to 2023.

2.3.2. Keyword Clustering

Using CiteSpace to cluster the keywords that appear, a clustering map of the keywords in Figure 2 is formed. The labels of each cluster are keywords from the co-occurrence network, and the larger the number of cluster numbers, the fewer keywords are included in the cluster.

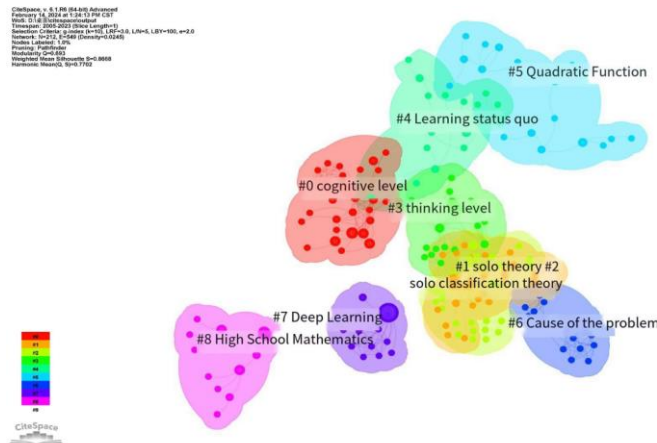


Figure 2: Keywords clustering map.

2.3.3. Research Topic

According to Figure 2, and through further study and analysis of relevant literature, it is found that the application of The SOLO Taxonomy in middle school mathematics from 2005 to 2023 can be roughly divided into four major aspects: core literacy, deep learning, analysis and compilation of test questions, teaching strategy and teaching evaluation.

2.3.4. Core Literacy

In 2022, based on the SOLO Taxonomy, Tang Dengfeng classified data analysis literacy into four dimensions, further refined the four levels, and designed the dimension level framework, which was used as the scoring basis for data analysis literacy test, to further study the teaching design of project-based activities in high school mathematics[3].

In 2023, Ma Shi and Yong Longquan, in order to better understand the evaluation function of college entrance examination questions, took the mathematics B test questions of the National College Entrance examination in 2022 as the research object, analyzed the characteristics of college entrance questions under core literacy based on the SOLO Taxonomy, and studied its examination of core literacy of mathematics and the level of thinking. It provides some new thinking for mathematics teaching in high school[4].

In summary, it can be seen that using the SOLO Taxonomy can effectively assess students' core literacy and thinking level, which is conducive to students' deep learning. Teachers can better understand students' learning status and thus propose reasonable teaching strategies.

2.3.5. Deep Learning

Mathematics deep learning means that on the basis of understanding knowledge, students can integrate old and new knowledge to solve more complex problems, master mathematical thinking methods, develop mathematical core literacy, and improve the level of thinking.

In 2022, based on the SOLO Taxonomy, Zhu Jiayi proposed the principles, strategies and implementation plans for high school mathematical modeling teaching based on deep learning[5].

In 2023, Li Jiamin classified the results of students' learning "series of numbers" with the SOLO Taxonomy, evaluated the effect of students' deep learning, and finally gave three teaching suggestions: Constructing knowledge network with the help of mind mapping to gradually activate students' thinking; Organic integration of teaching content through unit teaching highlights the essence of mathematics; Reasonable setting of teaching situation, experience the process of knowledge generation.

To sum up, the SOLO Taxonomy can be used to effectively evaluate students' deep learning, so as to put forward reasonable teaching strategies.

2.3.6. Analysis and Preparation of Test Questions

In 2022, based on SOLO theory, Zhang Qianming explored the examination of the core literacy of mathematical operation in college entrance examination questions. Through the correlation and consistency analysis between the evaluation level of SOLO theory and the level of mathematical operation literacy, he ordered the examination questions consistent with the level of SOLO corresponding to the operational level to effectively test the learning results of candidates[6].

In 2023, Zhao Yangji did research on the SOLO Taxonomy, setting a set of SOLO level criteria for evaluating mathematics questions in the college entrance examination, and roughly mastering the key directions of mathematics advanced examination questions, so as to help students learn with a certain target and help teachers set teaching priorities.

In summary, we can analyze the structural hierarchy of mathematics questions in the middle school entrance examination using the SOLO Taxonomy. The knowledge module of the examination paper contains four hierarchical structures: single point structure (U), multi-point structure (M), correlation structure (R) and abstract structure (E). By analyzing the distribution of various hierarchical structures and summarizing the characteristics of propositions, it can guide learning and teaching. In addition to analyzing test questions, scholars are also exploring the use of this theory to control the difficulty and differentiation of test questions, so as to achieve the basic, selective and developmental goals of the new curriculum standards.

2.3.7. Teaching Strategy and Teaching Evaluation

In 2023, Wu Chunxiao and Huang Zhixin selected the three dimensions of knowledge, method and

scientific reasoning to construct a hierarchy framework of scientific reasoning ability based on the SOLO Taxonomy[7]. Based on the hierarchy framework established, teachers could better assess the status quo of students' scientific reasoning ability and sort out teaching objectives more systematically.

In 2023, Zihao and Jianmin Shen designed the concept teaching of function in high school based on the SOLO Taxonomy, constructed a detailed evaluation table for mathematical abstract literacy, and explained the steps of applying the evaluation table in detail.

To sum up, through the hierarchical structure of the SOLO Taxonomy and combining with students' "recent development area", a step-by-step teaching strategy is designed to promote the enthusiasm of students at different thinking levels, which is conducive to the development of students at different levels. Based on the SOLO Taxonomy, the evaluation framework is constructed, and relevant examples, exercises and examination questions are designed to achieve the consistency of teaching evaluation more effectively.

3. Conclusion and Suggestion

CiteSpace can help researchers to have a deep understanding of the latest development of the discipline, so as to better predict the future development trend, and help them to find topics to be further explored. Emergent words refer to the sudden increase in the cited frequency of specific literature in a certain period, which can provide researchers with the latest development and direction of the discipline, as shown in Figure 3.

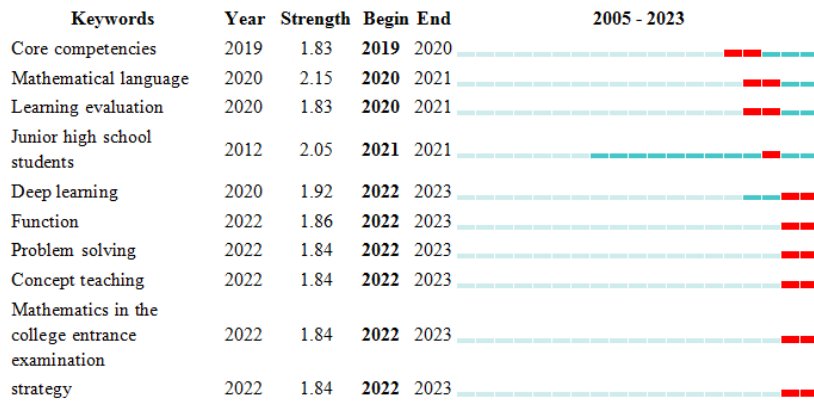


Figure 3: Keywords emergence graph.

As can be seen from Figure 3, more hot keywords appear around 2020-2023. At present, the most popular ones are Deep learning, Function, Problem solving, Concept teaching, Mathematics in the college entrance examination, strategy.

The author thinks that the SOLO Taxonomy's research on mathematics education can be thoroughly explored from the following aspects:

(1) Guide stratified teaching

The SOLO Taxonomy has been extensively applied to the analysis and compilation of test questions. Therefore, we can stratify the SOLO taxonomy according to the difficulty of the assignment and design a basic assignment framework, so as to ensure the effectiveness of the assignment and better guide the teaching.

(2) Construct a formative teaching evaluation model based on the SOLO Taxonomy

Using the SOLO Taxonomy to conduct hierarchical assignment design and hierarchical evaluation is a thought for constructing formative model of daily teaching, which promotes students' learning enthusiasm and deep learning ability.

(3) Develop curriculum resources

Using the SOLO Taxonomy to compile formative assessment curriculum resources of a system, students can integrate new and old knowledge on the basis of understanding knowledge to solve more complex problems, master the thinking methods of mathematics, develop the core quality of mathematics

and improve the level of thinking.

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