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Improving Students' Scientific Writing Skills through Discovery Learning in Science Learning: A Systematic Review

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Abstract: Scientific writing skills are essential for students to express ideas or thoughts in various media such as practicum reports. This skills can be trained through the implementation of learning models that can empower science process skills, namely discovery learning. This study aims to analyse various articles related to the implementation of discovery learning models in science learning to improve students' scientific writing skills. This research is a systematic review with the PRISMA method using the keywords "discovery learning" and "writing skills" during the last 10 years. There are 7 articles via Scopus reviewed from 2013 – 2023. The results of the systematic review analysis showed that the implementation of the discovery learning model in science learning can improve students' scientific writing skills that consist of various aspect and criteria. Students' learning activities in each syntax of discovery learning are suitable to empower each aspect of this skills. The systematic review of various articles on the implementation of the discovery learning model is expected to be a reference for science teachers, especially in learning biology to improve students' scientific writing skills.

Keywords: Discovery learning model; Science learning; Scientific writing skills.

Introduction

The fundamental goal of science learning is to develop students' ability to practice science in real life (Krishnamoorthy, 2023). This is in line with the educational objectives in the Merdeka Curriculum implemented in Indonesia today (Hutabarat et al., 2022). The independent learning program in the Merdeka Curriculum provides opportunities for students to explore insights and skills including in science learning. Science learning must be carried out using a student-centered scientific approach with demands for mastery of 21st century skills consisting of four main domains of literacy, inventive thinking, effective communication and high productivity (Lavi et al., 2021; Wan Husin et al., 2016). These four domains can be presented in the form of scientific writing as a result of empowering science process skills (Turiman et al., 2012).

Scientific writing skills can be defined as a form of communication skill that facilitates students to express ideas or thoughts and build understanding as a science learning goal (Sari et al., 2021). Scientific writing skills are also useful for developing imagination skills, improving language mastery, and increasing self-confidence (Oppenheimer et al., 2017). Scientific writing skills are one of the indicators of students' learning success in science learning (Iftanti, 2016). This skill reflects their ability to analyse and reflect on the results of their thinking which is included in higher order thinking skills (Sari et al., 2021).

Various research results show that scientific writing not only plays a role in generating knowledge (McLure, 2023), but also builds a better understanding of the main ideas of science (Cetin & Eymur, 2017). Scientific writing activities such as writing explanations, synthesis analysis and confirmations also require learners to internalize content and justify their answers (Owen et al., 2023). Thus, scientific writing skills can help learners develop a better understanding of science concepts and literacy (Cetin & Eymur, 2017; Rauschenbach et al.,

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2018). Although scientific writing skills are essential in science learning, students' mastery of these skills is still low (Suprayogi et al., 2021). The results of observations made in one of the schools in Solo Raya show that the scientific writing skills of students at the high school level are still relatively low. The observation results show that students have difficulty in formulating hypotheses, drawing up experimental designs, drawing conclusions according to relevant data, and explaining the advantages and limitations of the experiments. This is in accordance with the research of Haryono & Adam (2021) which shows that the scientific writing skills of students in Indonesia still need to be improved because their knowledge of how to write the results of experiments is not in accordance with the standards of scientific reports.

The efforts to improve scientific writing skills are a challenge for teachers in schools. One solution that can be applied to improve scientific writing skills is to apply a learning model that practices science process skills for students. The learning model that is in accordance with these characteristics is discovery learning. According to Njoo & De Jong, (1993), the discovery learning model has a syntax consisting of transformative processes including orientation, hypothesis generation, hypothesis testing, and conclusion; and regulative processes including planning, monitoring, and evaluation. Therefore, this study carried out a systematic review to analyse various articles related to the implementation of the discovery learning model in science learning to improve students' scientific writing skills. This research is expected to provide additional references for teachers in science learning, especially biology to improve students' scientific writing skills.

Method

The method used in this literature review research is the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) method (Peixoto et al., 2021). There were 10 articles found based on searching with this method. After being analysed based on the suitability of the specified criteria, 7 articles from Scopus were obtained that met the research criteria. Referring to this PRISMA method, several stages are carried out in selecting the articles to be analysed, including (Peixoto et al., 2021):

1. Defining Literature Eligibility Criteria

The inclusion criteria for this article consist of: (a) The article is written in English and has an international reputation; (b) Articles are included in education and science journals; (c) Journal publishing year from 2013-2023; (d) Journals that can be accessed in full.

2. Defining the Source of Information

In this research, the source of information used comes from the SCOPUS online database.

3. Literature Selection/Screening

In the selection of this literature there are two steps that are carried out, including: (a) Selection of keywords consisting of the words "discovery learning" and "writing skills"; (b) Complete reading of the journals obtained to determine whether they meet the eligibility criteria. There are 10 articles found at this step.

4. Data Collection

Data collection in this study was carried out manually by extracting data consisting of author names, journal titles, research results, and inference. At this steps, 7 articles are obtained that met the criteria, which were then used as the main data source.

5. Data Selection

The information taken from each journal consists of: (a) Application of discovery learning model in science learning; (b) Indicators of scientific writing skills; (c) Effect of discovery learning mode on scientific writing skills.

The results of the literature selection using the PRISMA method are described in the following scheme:

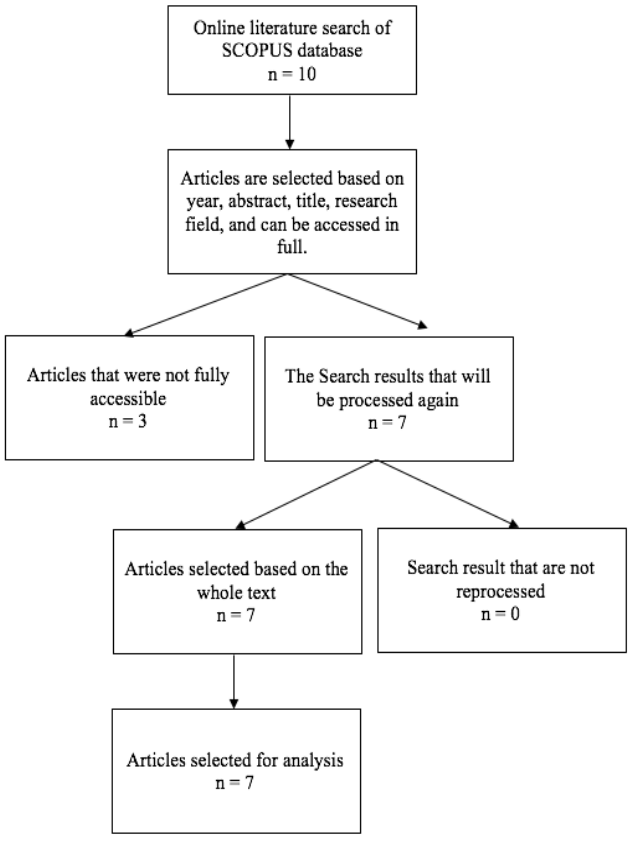

Figure 1. The selected articles through PRISMA method

Result and Discussion

By using the PRISMA method, 7 articles were obtained that met the eligibility criteria. The seven articles were obtained from online data based Scopus with the following distribution (Figure 2).

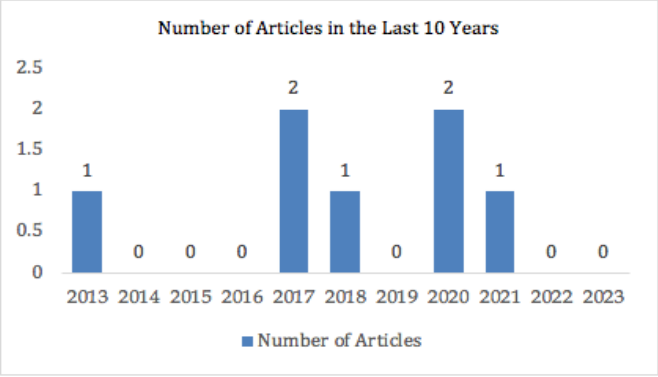

Figure 2. Articles Distribution in the Last 10 Years

The literature review analysis in Figure 2 shows that in 2017 and 2020 there were 2 articles each related to the implementation of the discovery learning model on students' scientific writing skills. In 2013, 2018, and 2021 there was only 1 article each. While in 2014, 2015, 2016, 2022, and 2023 there were no articles related to the application of the discovery learning model to students' scientific writing skills. The limited number of articles included in this study can be attributed to several factors. First, the use of narrowly defined keywords during the literature search in the Scopus database may have restricted the breadth of relevant studies retrieved. Second, access to full-text articles was limited, as not all identified publications were available in full. Third, the study utilized only a single database, namely Scopus, which may have excluded potentially relevant studies indexed in other databases. Lastly, the application of strict inclusion and exclusion criteria, such as specific publication years, language restrictions, and a focused scope on science education research, further narrowed the selection of eligible articles. All articles that have met the eligibility criteria are then analysed in Table 1.

Table 1. Journal Analysis of the Implementation of Discovery Learning on Scientific Writing Skills

Author	Title	Result	Inference
A. M. R. P Bopegedera (2021)	Student-Driven, Curriculum-Embedded Undergraduate Research Experiences (SD-CUREs) in the Senior Chemistry Curriculum and its Impact on Students	Curriculum-embedded undergraduate research experiences (CUREs) that implement discovery learning in chemistry courses can positively build student expertise in analytical instrumentation, improve research and writing skills, and provide support to students in developing research questions and laboratory protocols (Bopegedera, 2021).	The application of discovery learning in the learning process has the potential to build students' scientific writing skills.
Kevin A. Scott; Alexander Marciniak; William G. Benson; & Robin Polt (2020)	Lessons in Stereochemistry: Resolution, Synthesis, and Characterization of Chiral Compounds	Chemistry learning with discovery learning are useful for improving students' critical thinking skills and writing skills (Scott et al., 2020).	The discovery learning model in chemistry lectures can build students' scientific writing skills.
Musdizal & Rudi Hartono (2020)	The Influence Of Discovery Learning Method And Video On Students' Writing Skill	The discovery learning model combined with learning videos has a significant impact on improving the writing skills of the students in MAN 1 Sungai Penuh (Musdizal & Hartono, 2020).	The discovery learning model can be integrated with certain learning media to improve students' writing skills.
Wei Chen (2018)	Introduction to Research: A New Course for First-Year Undergraduates Students	The implementation of discovery learning in introductory research courses for first-year chemistry students can improve the ability to write practicum reports. Practicum report writing activities build students' intellectual appreciation of scientific disciplines and improve scientific writing skills (Chen, 2018).	The discovery learning model can build the ability to write practicum reports. Practicum report writing activities can improve students' scientific writing skills.
Lindsay B. Wheeler; Charles P. Clark;	Transforming a Traditional Laboratory to an Inquiry	Discovery-based curriculum that encompasses teaching theory,	The implementation of the discovery learning model

Author	Title	Result	Inference
Charles M. Grisham (2017)	Course: Importance of Training TAs When Redesigning a Curriculum.	pedagogy, and practical aspects in the laboratory allows students to master chemistry concepts while learning to think and act like a scientist (Wheeler et al., 2017).	allows students to act like scientists in designing experiments and communicating the results of experiments in the form of scientific writing.
Pinar Seda Cetin & Guluzar Eymur (2017)	Developing Students' Scientific Writing and Presentation Skills through Driven Inquiry: a Systematic Review	Argument-driven inquiry (ADI) model helps students improve their scientific writing and presentation skills. The scientific writing and presentation skills of students who initially scored 30/65 before treatment increased to 50/65 after participating in learning with the inquiry or discovery learning model (Cetin & Eymur, 2017).	The inquiry or discovery model can improve students' scientific writing and presentation skills before and after following the learning model.
Jeremy M. Carr (2013)	Using a Collaborative Critiquing Technique to Develop Chemistry Students' Technical Writing Skills	The discovery learning model with the "collaborative critiquing" technique can improve students' practicum report writing skills (Carr, 2013).	The discovery learning model can improve students' experimental report writing skills.

Table 1 shows that the implementation of the discovery learning model in science learning can improve students' scientific writing skills. Discovery learning is a learning model developed based on constructivism theory (Njoo & De Jong, 1993). Constructivism theory believes that students are active knowledge obtained (Chuang, 2021; Fernando & Marikar, 2017). The discovery learning model not only guides students in understanding science concepts but also familiarizes students in completing tasks (Wang et al., 2023). The concepts discovered during the learning process are expected to reduce students' misconceptions in science learning (Wartono et al., 2018).

According to Veermans (2003), discovery learning syntax consists of orientation, hypothesis generation, hypothesis testing, conclusion, and regulation. Learning activities in each discovery learning syntax reflect the learning events of students (Suardana et al., 2018). learners in developing their own knowledge (Dale H. Schunk, 2012). The implication of constructivism learning theory on the discovery learning model is that the learning activities contained in the syntax lead students to be able to find problems and construct knowledge based on what is already known and new

Pandey (2020) states that there are nine instructional events according to Gagne, such as gain attention, inform learners of objectives, stimulate recall of prior learning, present the stimuli, provide learning guidance, elicit performance, provide feedback, assess performance, and enhance retention and transfer. In each of these instructional events, there is a cognitive process that learners experience in acquiring knowledge about the topic being studied. The following is the integration between instructional events according to Gagne, the cognitive process experienced by students, and the syntax of discovery learning (Table 2)

Table 2. Integration of Gagne's Instructional Events and Cognitive Processes in Discovery Learning Syntax

Gagne's Instructional Events (Pandey, 2020)	Cognitive Process (Woo, 2016)	Discovery Learning Syntax (Veermans, 2003)
Gain attention: Provide stimuli to ensure that the incoming instruction is received.	Reception	Orientation
Inform learners of objectives: Telling students what they will be able to do after the lesson	Expectancy	Orientation
Stimulate recall of prior learning: Requesting recall of prior knowledge	Retrieval	Orientation
Present the stimuli: Providing and displaying the content	Selective perception	Orientation
Provide learning guidance: Providing relevant information to improve comprehension	Semantic encoding	Orientation

Gagne's Instructional Events (Pandey, 2020)	Cognitive Process (Woo, 2016)	Discovery Learning Syntax (Veermans, 2003)
Elicit performance: Requesting a response to the demonstrating learning	Responding	Hypothesis generation Hypothesis testing, Conclusion
Provide feedback: Giving learners timely feedback on their performance	Reinforcement	Regulation
Assess performance: Giving feedback on additional performance of learners for reinforcement	Retrieval	Regulation
Enhance retention and transfer: Providing a variety of exercise to help generalize the ability	Generalization	Regulation

Learning activities in each discovery learning syntax trigger students to develop scientific writing skills (Musdizal & Hartono, 2020). Scientific writing skills can be interpreted as a form of communication skills that facilitate students to express ideas or thoughts and build understanding related to science learning objectives (Sari et al., 2021). One type of scientific writing produced by students in science learning is an experiment report. According to Haryono & Adam (2021), an experiment report as a simple form of scientific writing has components including Introduction, Hypothesis, Methods, Results, Discussion, Primary Literature, and Writing Quality. To be able to produce quality scientific writing, students are required to master scientific writing skills (Valero Haro et al., 2019). This skill can be practiced in learning through the discovery learning model (Harvey et al., 2018). The following is an integration between discovery learning syntax, scientific writing components and scientific writing skill criteria that can be practiced to students (Figure 3).

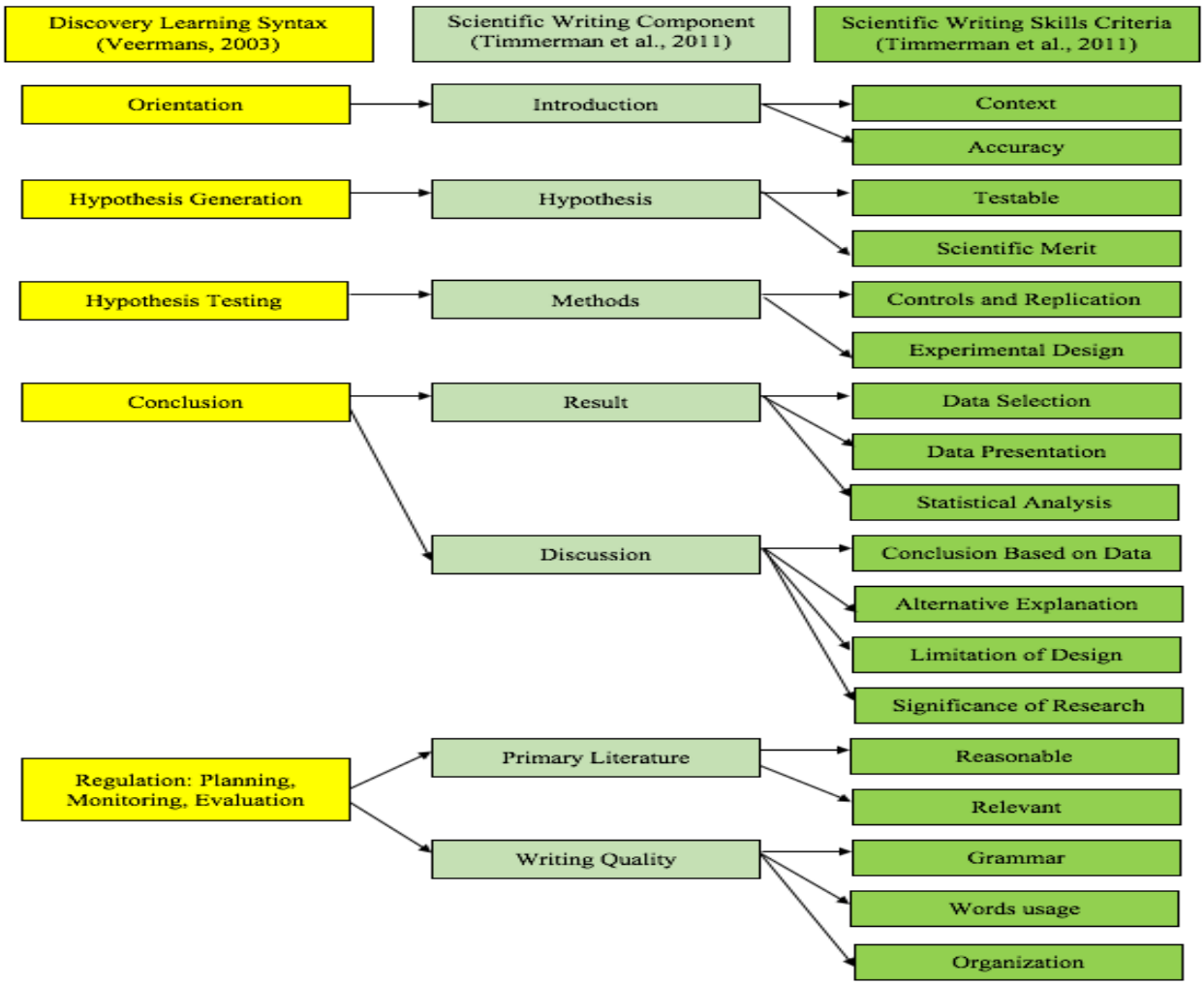

Figure 3. Relationship between Discovery Learning and Scientific Writing Skills

First, at the orientation stage, learners are given stimulation to develop their ideas related to the problem domain (Veermans, 2003). Learning activities at the orientation stage include observing problems, digging up information about problems, making connections between existing knowledge and current problems (Druckman & Ebner, 2018). The output of this process is that students can write a research question that will be studied further through experimental activities (Veermans, 2003). This activity can be used to develop one of the components in scientific writing, which is the introduction. The criteria for writing skills needed in making a good introduction can be seen from two things, such as context and accuracy (Timmermana et al., 2011). Context in the introduction must show a clear understanding of the urgency of the problem being discussed (Balta, 2018; Pisano et al., 2021; Timmermana et al., 2011). In addition, the introduction must show accuracy regarding relevant content knowledge and show background information including various appropriate terminologies (Balta, 2018; Pisano et al., 2021; Timmermana et al., 2011).

Second, the hypothesis generation activity in the discovery learning model. At this stage, students conduct learning activities in the form of formulating hypotheses based on the problems found (Veermans, 2003). This learning activity supports students in writing the hypothesis part of the experiment report. The criteria for writing skills in formulating a good hypothesis are testable and scientific merit (Bäckryd et al., 2015; Timmermana et al., 2011). The hypothesis must be testable in the sense that it can be clearly described, and in accordance with scientific provisions (Bäckryd et al., 2015; Timmermana et al., 2011).

Third, students' activities at the hypothesis testing stage. At this stage, students must design and carry out experiments that test the hypothesis, collect data from the experiments, and interpret the results (Veermans, 2003). This learning activity supports learners in writing experimental methods. The criteria for scientific writing skills in developing good experimental methods are determining appropriate variables and appropriate experimental designs that can test hypotheses (Lavi et al., 2021).

Fourth, learning activities at the conclusion stage. The learning activity carried out by students in this stage is to review the hypothesis based on the evidence generated in the hypothesis testing process. Students must decide whether the evidence matches the predictions obtained from the hypothesis, or identify discrepancies between the evidence and predictions. This may lead to revision of the hypothesis and/or generation of a new hypothesis (Veermans, 2003). The analysis in Figure 2 shows that this learning activity can practice students in writing result and discussion in the experiment report (Timmermana et al., 2011).

The criteria for writing good results include data selection, data presentation, and statistical analysis. Data selection criteria must be comprehensive, accurate, and relevant. Data presentation is in accordance with the right format, data is labelled appropriately, including units. Graph axes are appropriately labelled and scaled as well as informative and complete captions. In addition, there is also statistical analysis in accordance with the hypothesis being tested (Timmermana et al., 2011).

Furthermore, the criteria for writing a good discussion in an experiment report are conclusion based on data, alternative explanation, limitation of design, and significance of research (Greenberg, 2015; Timmermana et al., 2011). Conclusion based on data means that conclusions are drawn clearly and logically based on the data obtained. There is a logical flow of reasoning from hypothesis to data to clearly explained conclusions. If there is any contradicting data, it is adequately discussed (Greenberg, 2015). Alternative explanation indicates the existence of alternative explanations that strengthen the interpretation of data to support the hypothesis (Greenberg, 2015). Limitation of design indicates an explanation regarding the limitations of the experimental design and the data obtained (Greenberg, 2015). Significance of research indicates an explanation of the significance and usefulness of the experimental results (Greenberg, 2015).

Fifth, learning activities at the regulation stage. Learning activities at the regulation stage include determining goals and determining how to achieve these goals (planning). Monitoring the steps taken in learning. As well as, evaluating the steps taken in learning and the results of the findings related to the objectives specified (Veermans, 2003). This learning activity has implications for the components of scientific writing, which are planning in selecting primary literature and monitoring and evaluating writing quality. The criteria for skills in selecting primary literature are reasonable and relevant (Pisano et al., 2021). Meanwhile, the criteria for determining writing quality can be seen from the suitability of grammar, word usage, and organization of the writing presented (Fang & Wang, 2011; Pisano et al., 2021).

Conclusion

Based on the literature review with the PRISMA method, it can be concluded that the implementation of the discovery learning model can improve students' scientific writing skills. This is because the learning experience obtained by students in each syntax of the discovery learning model is in accordance with Gagne's

instructional events so that students can experience a series of cognitive processes to gain knowledge. Each learning activity in the syntax of the discovery learning model is also aligned with the components of scientific writing such as students' experiment reports so that they can practice and improve the various criteria for scientific writing skills that have been mentioned.

This literature review provides insight for teachers in designing science lessons that apply discovery learning models that not only promotes active learning but also foster students' scientific writing skills. Teachers are encouraged to intentionally design learning activities that simulate authentic scientific inquiry through each syntax of discovery learning model, allowing students to develop their conceptual understanding and scientific writing skills.

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Author Contributions
O.P conceived of the presented idea. O.P designed and performed the literature revies, derived model, and analysed the data. B.S and H provide guidance, critical feedback, and supervised the research. All authors discussed the results and contributed to the final manuscript.

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Conflicts of Interest
The authors declare there is no conflict of interest.

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