The Trend of Critical Thinking Studies in Biology Education through Online Learning: A Systematic Review

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ABSTRACT

Biology teachers and students in society 5.0 are expected to show critical thinking skills (CTS) in solving problems or making decisions. Thus, it is important to know how the CTS are nurtured through online learning. The trend of studies on these issues needs to be explored. This research aims to map the trend of studies on nurturing the CTS through online learning by reviewing some articles published within 2018-2020, considering 1) the online learning, 3) topics in biology, 4) teaching methods, and 5) instruments of CTS. Following the systematic review of the PRISMA Method, articles were screened from Google Scholar. The keywords were "critical thinking", "biology education", "online learning", and "Indonesia", which resulted in 23 articles to be further reviewed. The findings show that CTS’s research trends using online learning have increased due to the COVID-19 pandemic that requires students and teachers to distance studies. The most used online learning was digital learning. The researchers used various topics in biology to measure students’ CTS using online learning but mainly genetics and cell biology. The most widely used teaching method is blended learning and online discussion which various learning models can combine learning methods or learning media. The test is mainly used as an instrument to measure CTS with various indicators presented by experts. Research on CTS using online learning needs to be further explored to increase the quality of the study.

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Introduction

The 21st century is marked as the era of Society 5.0, where information and technology are spreading and developing very rapidly. It's no wonder that experts categorize the 21st century as a century of knowledge. In this century, knowledge intertwines and synergizes quickly, which requires everyone to adapt and compete in education and work. Higher Order Thinking Skills (HOTs) are essential in the face of intense competition in this knowledge age. The logical consequence is that the existence of human resources becomes a complete device that has intelligence and mastery of knowledge and equips itself with HOTs. CTS is one of the HOTs needed to deal with the increasing rate of change, complexity, and interdependence in the 21st century (Ben-achaim, Ron, & Zoller, 2000; Dwyer, Hogan, & Stewart, 2014). This skill is also a metacognition process and includes high-level cognitive skills (Abrami et al., 2008; Ben-achaim et al., 2000; Dwyer, Hogan, Harney, & Kavanagh, 2017; Noone & Hogan, 2017).

Partnership for 21st Century Skills (P21), Assessment and Teaching 21st Century Skills (ATC-21S), and Indonesian Partnership for 21st Century Skills Standards (IP-21CSS) state that CTS is one of the skills needed in this century. CTS is important to be trained for students compared to other HOTs skills because other 21st century skills involve CTS so that CTS is the essential skill among other 21st century skills. One of the 21st century skills is 4C, namely CTS and problem solving skills, creative thinking and innovation skills, communication skills, and collaborative skills (Buchert, 2014; Fong, Sidhu, & Fook, 2014, Kivunja, 2014; Marope, 2015). Education can accommodate demands for the intellectual ability of students to think smartly and selectively in choosing valid and relevant information. It can train students' cognitive, affective, and psychomotor skills to form a character that will affect students' attitudes in life (Kozleski, Yu, Satter, Francis, & Haines, 2015). Education can train people to have HOTs (Angeli & Valanides, 2009; Ben-achaim et al., 2000; Zenker, 2016). CTS has been widely studied in education and other fields of natural science such as biology, physics, chemistry, economics, environmental sciences, and art (Islek & Hursen, 2014; Nuri, Sajidan, Oetomo, Prasetyanti, & Parmin, 2019). Entering Society 5.0, teachers and students are required to master digital learning, such as online learning. Online learning is a method for teaching and learning connected to the internet, increasing student motivation and attention and increasing the effectiveness and efficiency of information delivery. Learning media is important to help students in the learning process. Online learning was developed as an open access learning method which expected to attract the attention of students, provide motivation to students, therefore information conveyed through the media can be captured by students and tested on teaching and learning to see the practicality of using the online learning. Online learning has the scope of administration, delivery of material, assessment, monitoring, and communication. Materials in pedagogical and professional competencies, which are made with multimedia packaging (text, animation, video, and sound) in the online learning will accelerate the mastery of science and technology that can improve the quality of learning (Alfianto & Karyanto, 2019). There are many studies show that online learning media are successfully used as a learning environment. Therefore, online learning attracted a lot of attention from educators, and they started trying to find out how online learning could be used in educational settings to aid their teaching (Durak, 2017).

The 21st century assessment must teach students to apply CTS (Binkley et al., 2012). CTS needs to be developed and trained for students to practice high-level thinking habits, decision-making by scientific truth, problem solving, and improvement in learning outcomes (Suyanto, Susanto, & Linuwih, 2012; Zhang et al., 2017; Živković, 2016). The success or failure of education depends on the learning process experienced by students (Siti Rahmah dan Muhammad Kusas, 2016). According to the importance of CTS and Society 5.0, students must be equipped with the knowledge to produce CTS, produce works to compete in the
international world (Nuri et al., 2019), and mastery of digital learning media. Therefore, the purpose of this study is to identify the trends of CTS research in biology education through online learning from 2018 to 2020, including 1) the publication year, 2) online learning media, 3) topics in biology, 4) teaching methods, and 5) instruments of CTS.

Methods

The method used in this study is a systematic review with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses). PRISMA is a guideline to assist researchers in preparing data search protocols presented in systematic reviews. This guideline contains protocols for reviewing articles to ensure accurate and comprehensive results under the research objectives. Components in PRISMA include identification, screening, and eligibility (FIGURE 1) (Liberati et al., 2009; Moher, Liberati, Tetzlaff, & Altman, 2009). Researchers obtained the articles from Google Scholar and limited them from 2018 to 2020. The determination of the year is based on previous systematic review studies that have examined CTS in biology education in 2010-2017 (Susetyarini & Fauzi, 2020) and previous systematic review studies on biology studies in Indonesia in 2012-2017 (Haviz & Ridho, 2019), so this research continues the previous research by adding the keywords “online learning”. The keywords used in this study were "critical thinking", "biology education", "online learning", and “Indonesia”. The PRISMA method is produced 23 articles related to the keywords. Inclusion and exclusion criteria are included in this study to find the relevant articles (TABLE 1).

TABLE 1. A Criterion of inclusion and exclusion articles

| Criterion          | Inclusion                                      | Exclusion                                      |
|--------------------|------------------------------------------------|------------------------------------------------|
| Publication Year   | 2018 to 2020                                   | Articles outside these years                   |
| Country            | Indonesia                                      | Articles outside Indonesia                     |
| Sample group       | University student, senior high school (SHS), and junior high school (JHS) | Articles outside these criteria including elementary, kindergarten, and early childhood |
| Language           | English and Indonesian Language                | Articles outside these criteria                |
| Study focus        | Biology education, CTS, online learning        | Articles outside these criteria                |
| Type of article    | Qualitative, quantitative, mix method, R&D, CAR | Articles outside these criteria, including systematic review, literature review, etc. |
| Database           | Google Scholar                                 | Articles outside these criteria                |

The researchers used the Microsoft Access program to analyze the data. It was used to save the defined criteria and to create a database. We kept all the data obtained from the detailed analysis of the documents for each article. The reports were made by grouping the data according to the defined criteria using the questioning features.
Result and Discussion

Entering the era of Society 5.0, all sectors of life lead to digitalization, including the education sector. Education must be able to adapt to all current progress. Online learning is one of the systems that began to develop among academics to convey the learning process. However, CTS is one of the skills that remain the focus of research because this skill is the basis of HOTS. In this section, we present our findings to find out trends in research on CTS using online learning, which is restricted from 2018 to 2020 and produced 23 articles.

Publication Year

The articles on CTS and online learning from 2018 to 2020 are various (FIGURE 2). In 2018, there were only two articles, and in the year 2019, there were ten articles related to the keywords. 2020 was the peak year of research on CTS associated with online learning, which produced eleven articles. In 2020, the number of article publications on CTS using online learning had grown due to the COVID-19 pandemic conditions that require students and teachers to do distance studies. Researchers must be productive in producing articles related to HOTS to be trained on students, especially CTS. The published articles can be used as references by teachers to teach CTS in the pandemic era.

FIGURE 1. Flow Diagram of PRISMA Method

FIGURE 2. Publication Year of The Studies
Online learning media

Online learning is a method to distribute the subject matter and enable collaboration between students and teachers. Online learning allows teachers to receive assignments digitally and stay in touch with their students (Anggriawan, 2009). Online learning can use Edmodo, Google Classroom, Web, WhatsApp, Digital Learning, Google Meet, Zoom, and Gen21-cs (FIGURE 3). Four researchers use Edmodo, Google Classroom is used by two researchers, the web-based is used by five researchers, WhatsApp is used by three researchers, Digital Learning is used by seven researchers, and gen21-cs is used by two researchers. In comparison, one researcher per each uses Google Meet, Zoom, and Virtual lab. Gen21-cs is only used for genetic topics, and the same researcher makes this application. The use of a smartphone, digital media, and multimedia learning is included in the digital learning group.

| Online Learning Media | Number of Articles |
|-----------------------|--------------------|
| Virtual Lab           | 1                  |
| Zoom                 | 1                  |
| Google Meet          | 1                  |
| Digital Learning     | 5                  |
| WhatsApp             | 3                  |
| Web                  | 4                  |
| Google Classroom     | 5                  |
| Edmodo               | 7                  |
| Gen21-cs             | 2                  |

FIGURE 3. Online Learning Media

The web is a tool through which learning activities and learning resources can be accessed (Petchtone & Sumalee, 2014). The web is used in web-based learning that can be combined with other learning techniques to enhance students’ HOTs. One example of web-based learning is a web quest that requires scaffolding techniques where students get guidance from the teacher to achieve learning objectives. Web-based learning requires high motivation from students to solve the problems presented in education (Hidayah, Lumowa, & Boleng, 2018). Motivated students will influence the filtering of information and concluding. Furthermore, to improve CTS, web quest requires collaborative learning where students must work together to complete a project to reach the learning objectives (Averkieva, Chayka, & Glushkov, 2015). Based on the analysis, web-based learning combined with scaffolding and collaborative learning techniques can enhance students’ CTS (Tiruneh, Verburgh, & Elen, 2014).

According to Xu (2016), the learning content must be sequenced to support students’ deep understanding of CTS through online learning. This sequence can be based on the stage of student development, and the grade level studied based on a logical analysis (Plummer & Maynard, 2014; Shavelson, 2012) found in Learning Progression (LP). LP develops students’ potential to move towards a deeper understanding of the big ideas of science in a long period (Smith, Wiser, Anderson, & Krajcik, 2006). Shavelson (2012) states that learning progression is a sequence of more complex ways of reasoning about a series of ideas from simple to complex; it relies on instructions that interact with previous knowledge and construction of new knowledge to develop from beginners to beginners experts. Therefore, further research is needed on LP to improve student CTS using online learning media.
Google Classroom is part of G-Suite for Education which is bound with Drive, Hangouts Meet, Calendars, Forms, Docs, Slides, Sheets, and G-mail, which means these services can be utilized in the learning process (Ventayen, Estira, Guzman, Cabaluna, & Espinosa, 2018). It enables teaching and learning activities to be more productive and meaningful by simplifying assignments, increasing collaboration, fostering communication, and free access. Teachers can create classes, share materials, give tasks, send feedback, quickly see who has and hasn't completed a task, and immediately provide real-time grades and input. Students can view tasks on the assignments page, in the class stream, or on the calendar. They can share material and interact in the class stream or via email. All class material is automatically stored in the Google Drive folder.

Edmodo is a social networking learning platform aimed at teachers, students, and even parents of students. This social media benefits learning activities, providing a safe and easy way to create virtual classes based on class divisions such as at school (Durak, 2017). Some features in Edmodo are; a) Assignment, i.e., pages for assigning and uploading assignments. b) Gradebook, i.e., a page for giving grades to students. c) Polling, i.e., a page to check student activities. d) Quiz, i.e., a page for assessing students. e) Library, i.e., a page to provide learning material for students. f) Parents code, i.e., a page for students' parents in monitoring student learning activities (F. Dewi, 2014). Teachers and parents can see everything posted on it; therefore, cyberbullying and inappropriate content can be prevented (Cauley, 2013). Future studies are suggested to examine CTS in biology using online learning that has never been used before. Furthermore, researchers can develop online learning media that is appropriate to the characteristics of biology learning.

**Topics in Biology**

Biology is a discipline that has many topics that must be taught and mastered by students (FIGURE 4). Based on the results of a systematic review, many biology topics are used in research. Topics that have been studied in 1) JHS are human physiology and life organizational system, 2) SHS are bacteria, digestive system, environment, human physiology, and excretory system, and 3) the university is genetic, cell biology, histology, nonvascular plant, anatomy & physiology of human, animal, and plant, reproduction system and research. Researchers can use all topics using online learning in CTS research. The results of a systematic review show that topics in biology are thoroughly researched. However, some topics that are widely researched, although not significant, are cell biology and genetics. Future studies are suggested to examine the topic of biology, which is less researched using online learning to enhance students’ CTS.
The teaching methods that are widely used are blended learning and online discussion. The blended learning approach combines synchronous and asynchronous activities (Limiansi, Tias, & Devi, 2020). The blended learning approach can be combined with various learning models, learning methods, or learning media, such as the PDEODE-WEB model (Mailani, Zulfarina, & Syafii, 2020), Tri Hita Karana (THK) Device (N. P. S. R. Dewi, Adnyana, & Citrawathi, 2020), guided discovery (Suparini, Rusdi, & Ristanto, 2020), Project-based Learning (Permana & Chamisijatin, 2019; Putri & Hendawati, 2018), Problem-based Learning (Lukitasari, Purnamasari, Utami, & Sukri, 2019), and Edmodo-based blended learning model (Wahyuni, Gusti Made Sanjaya, Erman, & Jatmiko, 2019). Researchers most widely use the blended learning approach to connect various learning media such as real-time virtual classrooms and face-to-face classrooms using videos, pictures, etc. Online discussion is the second option in online learning. This method allows discussion members to improve their CTS. Online discussions can be combined with the PBL model (Y. Maryuningsih, Hidayat, Riandi, & Rustaman, 2019; Yuyun Maryuningsih, Hidayat, Riandi, & Rustaman, 2020), social media (Y. Maryuningsih, Hidayat, Riandi, & Rustaman, 2020), multimedia such as Virtual Class (Rakhmawati, Hasnunidah, & Priadi, 2020), and Open Educational Resources (Rahayu & Sapriati, 2018). The other teaching methods used are the anchored instruction model, PBL, elaboration model, BTEM-based web, argument-driven inquiry model, STEM, life-based learning, and guided discovery learning that can enhance students' CTS. The result can be seen in (FIGURE 5).
CTS instruments used in the studies are various, namely observation, questionnaire, test, interview, and document analysis (FIGURE 6). Researchers found the observation method in nine articles, the questionnaire method in eleven articles, the test method in seventeen articles, the interview method in four articles, and the document analysis method in three articles. The most widely used method is the test method as the core method in measuring student CTS. Other data gathering methods, such as interviews, questionnaires, and observations, are additional data collection tools.

The test instrument can be a multiple-choice, essay, open-ended question, and closed question. It is made based on indicators of critical thinking skills presented by experts. Rahayu & Sapriati (2018) use the CTS indicator from Ennis, which consists of building basic skills, providing a simple explanation, asking and answering questions, and setting strategies and tactics, resulting in a score of 80.7 (Rahayu & Sapriati, 2018). This finding is also done by Putri & Hendawati (2018). They use the CTS indicator from Ennis, which consists of defining terminology, focusing on questions, analyzing arguments, understanding and using graphs or mathematical concepts, completing and taking into account an assumption, and using ready knowledge. The result states that the analyzing arguments indicator gets the highest score in the high category. The focusing on questions indicator gets a low category, while the other indicators get the moderate category (Putri & Hendawati, 2018). Lukitasari et al. (2019) also use the CTS indicator from Ennis, which consists of providing a simple explanation, developing basic skills, drawing conclusions, providing a further explanation, and setting strategies and tactics (Lukitasari, Purnamasari, et al., 2019). In the same year, Lukitasari et al. (2019) used the CTS indicator from Avierkieva (2015) and Arifin (2012), which consisted of grammar, completeness, the consistency of information presented, creativity, defining, and developing information (Lukitasari, Hasan, & Murtafiah, 2019). In contrast to Maryuningsih (2019), who uses the CTS indicator from Facione, which consists of interpretations, analyzes, evaluations, inferences, and explanations that produce a score of 57.49.
FIGURE 6. Instruments of CTS

Conclusion

Teachers need to train students with CTS to deal with the increasing rate of change, complexity, and interdependence in the 21st century. Research trends on CTS using online learning from 2018 to 2020 have increased due to the COVID-19 pandemic conditions that require students and teachers to distance studies. The researchers used digital learning and various biology topics to measure students' CTS using online learning but mostly are genetics and cell biology. The most widely used teaching method is blended learning and online discussion. The researchers can be combining with various learning models, learning methods, or learning media. The test is mainly used as an instrument to measure CTS with various indicators presented by experts. The Research on CTS using online learning needs to be further explored to increase the quality of research.

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