Science learning oriented to higher order thinking in digital era

Cite as: AIP Conference Proceedings **2600**, 070003 (2022); https://doi.org/10.1063/5.0112450
Published Online: 30 December 2022

Didik Setyawarno and Atik Kurniawati

Science Learning Oriented to Higher Order Thinking in Digital Era

Didik Setyawarno[1, a)] and Atik Kurniawati[2, b)]

[1]*Department of Natural Science Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia*
[2]*Department of Biology Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia*

[a)] Corresponding author: didiksetyawarno@uny.ac.id
[b)] atik_kurniawati@uny.ac.id

Abstract. Science learning becomes very important in the development of students' higher-order thinking, especially in the current era which is entering the digital era. This article aims to discuss science learning oriented to the development of higher order thinking skills in the digital era. The method used is a literature study using various references, both books, journals, and other sources from the internet related to the topic of writing this article. The various sources were studied in depth to the practical stages in implementing the learning in the classroom. The results of the study show that science learning that is oriented to the development of higher order thinking skills is learning based on a scientific approach covering aspects of observing, asking, experimenting, associating, and communicating which are fully integrated in science process skills. As for the digital era, science learning that is oriented to the development of higher-order thinking skills is applied by using elements of digital-based technology such as simulations and virtual laboratories to make science lessons well understood and able to improve students' higher-order thinking skills.

INTRODUCTION

The problem of science learning currently faced in the global era, one of which is that science learning tends to be more than fact-based knowledge [1]. As a result, science learning becomes meaningless and cannot be fully understood by students. The science learning process is emphasized by how science is obtained, namely by a scientific approach carried out with an active learning process. A student-centred active learning process where a facilitator is the focal point of today's contemporary education system [2]. As educators, science teachers are one of the determining factors for the success and advancement of technology and civilization of a country. Today's rapid technological developments have brought a shift in views on science education from objective fact-based knowledge to practical activities that equip students' skills, attitudes, and values based on their understanding of science. The implementation of science learning, which mostly occurs in Indonesia, is still found to have various weaknesses [3]. These problems include science which is generally considered a study of facts related to nature and materials so that it has an impact on learning science that is less meaningful.

Meaningful science learning will be able to improve students' higher-order thinking skills. The importance of mastering higher order thinking skills is contained in several points of Competency Standards for School Graduates in Indonesia. The expected points are that students can build and apply information or knowledge logically, critically, creatively, and innovatively; demonstrate the ability to think logically, critically, creatively, and innovatively in decision making; and demonstrate the ability to analyze and solve complex problems [4]. Furthermore, the Government of Indonesia expects students to achieve various competencies by applying high-level thinking skills in the science learning process. These skills are skills, namely Critical Thinking, Communication, Creative Thinking, and Collaboration skills. These 4C skills are needed in the 21st century [5]. The problem faced to realize higher-order thinking skills is that science learning is not yet fully from the science domain. Science learning is still less meaningful for students if it is only oriented to facts and concepts.

Meaningful science learning must be able to develop things that are more than just knowledge, but also include processes, creativity, attitude, and application [6]. Science must be taught in certain ways in order to direct and encourage students to get optimal results in the learning process [7]. The fact that can be found in various schools is that science learning still focuses on the cognitive aspect only, it is still considered a collection of memorizing formulas and

The 3rd International Conference on Science Education (ICoSEd 2021)
AIP Conf. Proc. 2600, 070003-1–070003-6; https://doi.org/10.1063/5.0112450
Published by AIP Publishing. 978-0-7354-4289-4/$30.00

memorizing concepts [8]. Thus, it has an indirect impact, namely that students do not understand the various facts, concepts, principles, laws and science theories they learn. In addition, the learning objectives in the aspect of process skills and scientific attitudes are still not optimal in science learning. Especially with COVID-19 pandemic, which has changed various areas of life, including education, it has had a tremendous impact on the development of science learning programs in schools [9]. One of the most felt impacts is digital literacy. Before and at the beginning of COVID-19 pandemic, digital literacy in Indonesian society was still relatively low. Based on a survey conducted by the Directorate General of Aptika and Katadata in 2020, Indonesia is still on a scale of 3.47 from a scale of 4. These results reflect that Indonesia's digital literacy rate is still below a good level [10].

COVID-19 pandemic has changed the learning process from offline to online-based [11]. Digital literacy is currently experiencing a very rapid acceleration, so that it has a positive impact on all educators and students in the formation of digital literacy. One theory that can explain the formation of digital literacy is Bawden's conception that connects digital literacy with computer literacy and information literacy. According to Bawden, the concept of digital literacy is composed of four components, namely basic literacy skills (reading and writing), background information knowledge (intellectual level), skills in the field of information and communication technology, and attitudes and perspectives on information [12]. Skills in the field of information and communication technology are skills in creating or compiling digital content. This skill is a key competency in the field of digital literacy and involves the ability to assemble information or knowledge that is very useful for educators and students. Entering the pandemic period where learning is done online, high digital literacy skills can make it easier for students to follow every learning process (using various platforms). There are many science learning media that can be used in the online learning process. The digital media can be installed and used as a supporter in science learning, so that abstract science concepts can be understood well by students.

Learning media that is very diverse and computer-based is one of the characteristics of science learning in the 21st century. Media and technology are included in the scope of science learning technology. This means that the media in an educational perspective is a very strategic instrument in determining the success of teaching and learning processes [13]. Media is very helpful for educators or teachers, especially students, to accept and understand the material presented easily. The obstacle faced today is the use of digital-based technology in learning [14]. Revolution 4.0 has brought convenience in the use of digital media in the science learning process. The digital media include Phet Colorado, tracker analysis, visual analyzer, stellarium and so on, all of which are based on digital technology that is able to explain science concepts both concrete and abstract. Facts that have occurred so far are that teachers still encounter problems in operating technology and information as learning media, including the lack of teacher knowledge about technology and information, lack of technology and information facilities available in schools, the internet cannot reach all classes, and there is no obligation on the part of the school so that teachers who teach must use the latest ones [15]. The solution for science learning in the face of the digital era and global competency competition is the application of science learning with a scientific approach that is oriented to scientific literacy skills in the digital era by combining current information technology developments.

Based on the description above, this article will desribe science learning oriented to higher order thinking and digital technology that can be used in the science learning process. The science learning aspects studied include a comprehensive definition of science and how to teach science that is able to facilitate students to think at higher levels. The digital technology studied includes the definition of technology in the digital era and its use in science learning. The last aspect of this article examines how the implementation of higher-order thinking-oriented science learning is integrated with digital technology that is developing in the current era.

METHOD

The method used is a literature study using various references, both books, national journals, international journals, and other sources from the internet related to the topic of writing this article. These various sources were briefly and in depth reviewed to the practical stages of implementing the learning in the classroom. The reason for using the literature study method is based on the main purpose of writing articles, namely to examine theoretically how to develop high-order thinking-oriented science learning in the digital era.

RESULTS AND DISCUSSION

Science Learning Oriented to Higher Order Thinking

Science learning comes from the words learning and science. Science learning is basically an interdisciplinary field that studies how to teach science and how to learn science [16]. The goal of science learning is to better understand the cognitive and social processes that result in the most effective learning, and to use this knowledge to redesign classrooms and other learning environments so that people can learn more deeply and more effectively. Learning sciences basically include cognitive science, educational science, psychology, computer science, anthropology, sociology, information

science, neuroscience, education, design studies, instructional design, and other fields related to the teaching and learning process. The term science learning can be understood well if it is seen first the definition of learning and the definition of science itself. Learning is basically a process of student interaction with education and learning resources in a learning environment [17]. Science itself is basically a systematic observation, creation, analysis, and modeling of patterns that exist in the universe. This understanding is in line with the definition put forward by Jessani that science is generally regarded as the study of facts relating to the natural and material world [1].

Science which studies facts related to the natural world and matter has four dimensions as proposed by Chiappetta and Koballa, namely science as a way of thinking, science as a way of investigating, science as a body of knowledge, and science and its interactions with technology and society [18]. Based on the quote, there are four dimensions in science including ways of thinking, ways of investigating, body science and its relation to technology and society. The four dimensions are basically the application of the scientific approach used in studying science like a scientist who emphasizes higher-order thinking skills. Science as a way of thinking is a thinking activity to uncover, explain and describe natural phenomena. Science thinking includes belief, curiosity, imagination, reasoning, correction as well as being objective and open-minded. Science as a way of investigating is carried out using scientific methods that can be used to investigate various natural phenomena and phenomena. Investigations in science involve the formulation of hypotheses, observations, and experiments. Science as a body of knowledge is a collection of knowledge obtained through investigation or the scientific method. The body of science contains four dimensions of knowledge, namely factual knowledge (facts), conceptual knowledge (concepts), procedural knowledge (principles, laws, hypotheses, theories, and approaches) and metacognitive knowledge.

Good science learning will cover the four dimensions of knowledge that are integrated in science investigation activities. Science investigations are basically carried out using scientific methods applicable in science. Science is a special type of knowledge, having a very strict methodology; however, there is no general scientific method as is commonly believed by many members of the general public [19]. Therefore, it is most important for students to realize that the scientific method is a form of higher thinking, both the ability to analyze, criticize, or create which will be subject to review and repetition freely to reduce the level of uncertainty. Scientific method activities may include some or all of the following procedures in one form or another: observation, defining a question or problem, research (planning, evaluating current evidence), forming hypotheses, prediction of hypotheses (deductive reasoning), experimentation (hypothesis testing) , evaluation and analysis, peer review and evaluation, and publication [20]. These activities are a series of processes that students can use to gather knowledge about the world around them, increase knowledge, and try to explain why and/or how things happen. This method includes making observations, making questions, making hypotheses, conducting experiments, analyzing data, and making conclusions. Every scientific experiment that is conducted is an example of the scientific method in action, but it is also used by non-scientists in everyday situations.

Scientific method activities in science learning basically train students to think at higher levels. The scientific method activity as a whole is an activity of science process skills, both basic and integrated, so that it is oriented towards improving high-level thinking for the ability to analyze, criticize, or be creative from what they learn. Science process skills are grouped into two categories, namely basic and integrated skills [21-24]. Basic science process skills include observing, inferring, measuring, communicating, classifying, predicting, using space-time relationships and using numbers. Integrated science process skills include controlling variables, operationally defining, formulating hypotheses, formulating models, interpreting data and experimenting. These skills can be understood briefly as Fig. 1.

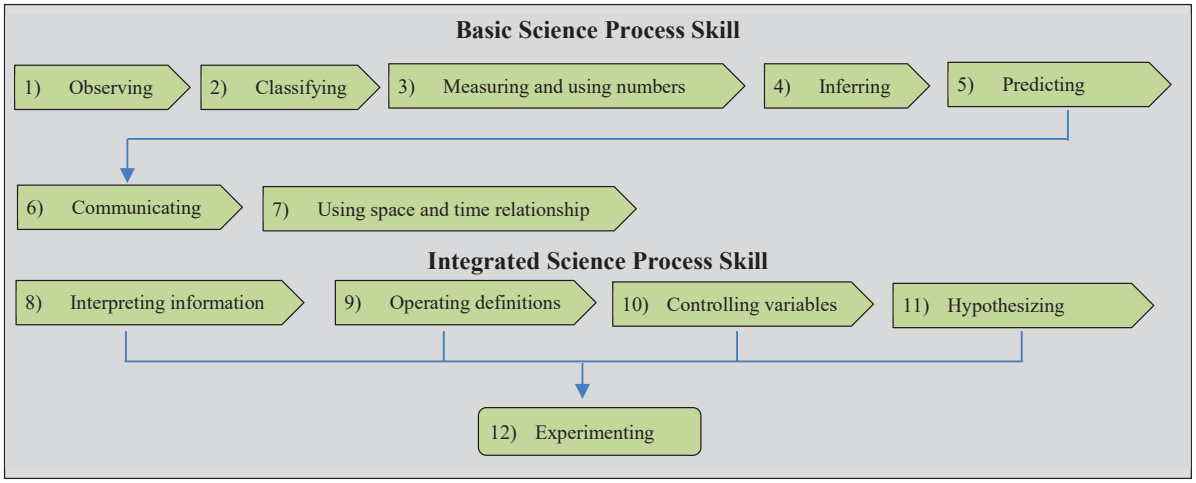


FIGURE 1. Basic and integrated science process skills

The relationship of the scientific method which is translated into science process skills with higher-order thinking skills in science learning can be explained by Table 1 [21].

TABLE 1. Scientific method activities in science process skills

No	Investigating Scientifically	Explanation
1.	Planning	From observations, ask a question, or pose a problem
		Find out what is currently known
		Identify and analyse problem and identify variables
2.	Conducting	From an hypothesis, testable statement, and research question
		Conduct trials, carry out the experiment, observe, measure and record data
3.	Processing	Organise data, calculate, construct graphs
		Analyse data: identify patterns or trends and relationship between variables
		Use science knowledge to develop explanations for patterns, trends or relationship in data
4.	Evaluating	Evaluate the findings in relation to hypothesis
		Evaluate the experiment and the methods used
		Publish

Table 1 basically describes the process of science in science research activities. The first step of the scientific process is to make observations and create problems. After that, students need to find out what is currently known. For example, when conducting an experiment, we want to make sure that we are not doing something that has already been done or proven. Therefore, researching a topic will provide students with information on which to base experiments and plans. The next step is to identify/analyze the problem and identify the variables. After that, students try to form a hypothesis: what students think will happen. After the hypothesis is formed, students conduct several trials to ensure its accuracy. After this step, the students must analyze the data and evaluate the findings compared to the previous hypothesis. Finally, students can publish the results of their investigations. Science process activities are closely related to higher-order thinking skills, namely in the aspect of analytical skills. The ability to analyze has three indicators, namely being able to distinguish relevant and irrelevant things, being able to organize information obtained from various sources, and being able to connect the parts that exist in a concept or problem. The ability to evaluate has two indicators, namely being able to examine existing facts and being able to criticize something that is deemed inappropriate or inappropriate. The ability to create is the ability to produce something that has three indicators, namely creating hypotheses or thoughts with certain criteria, planning problem solving steps, and producing new products.

Based on some of the descriptions above, it can be concluded that science or science is a science that studies natural phenomena through a series of scientific methods whose results are arranged in scientific products that can be applied to solve problems in everyday life in accordance with the nature of science (attitudes, processes and processes). , products, and technology). Based on the exposure of experts, it can be concluded that higher-order thinking skills are thinking skills where students must be able to analyze, evaluate and produce a new solution to the problems at hand, not just knowing and memorizing a concept. Science learning that is oriented to higher order thinking can be applied with learning based on scientific methods that are integrated with science process skills, including problem-based, project-based, or other investigative learning models.

Science Learning Technology in the Digital Era

Learning technology is basically an included term for material tools and theoretical foundations to support the learning process. The definition of a learning technology is not limited to high technology but is anything that enhances classroom learning in the use of mixed, face-to-face, or online learning. Etymologically, the word technology comes from the Greek, namely techne which means skill or knowledge, in other words it can be interpreted as knowledge related to skills or methods used to provide knowledge easily [25]. The formulation of the notion of learning technology has undergone several changes, in line with the history and development of learning technology itself. Educational experts who are very influential in the development of modern learning technology are Edgar Dale and James Finn who are known as the Cone of Experience.

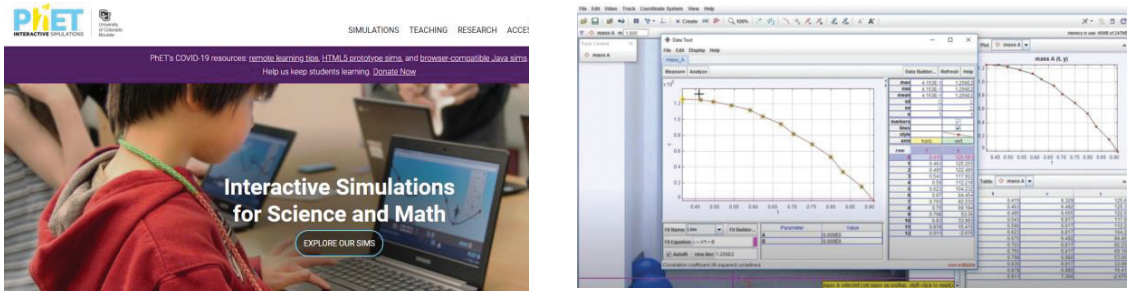
The Cone of Experience as stated by Edgar Dale and James Finn is the main foundation in the development of educational technology, including in science education. The development of modern learning technology is happening very rapidly in the current era, so the current era is also known as the digital era. Two educational experts who have made major contributions to the birth of modern learning technology are Edgar Dale and James Finn. Dale is famous for his cone of experience (The Cone of Experience). This cone of experience functions as a visual equivalent to the level of concrete and abstraction of teaching methods and learning media.

Several studies reveal that Science Education can be improved by using technology, namely computers, smartphones, tablets and different types of educational software [26]. Educational technology in English terms is called "instructional technology" or "Education technology". This kind of education that is prioritized is a communication

medium that is developing very rapidly which can be used in education. These technological tools are commonly called "hardware" including TV, radio, video, tape, computers, and others. Apart from that, education also uses technology called "software" including analyzing and designing sequences or learning steps based on the objectives to be achieved with a harmonious presentation method and assessment of success. Along with technological advances, the development of learning media is so fast, where each existing media has its own characteristics and abilities. From this, then arise structuring efforts, namely grouping or classification according to the similarity of characteristics or characteristics [27].

Science learning technology can be specified in five types, namely hardware, software, infoware, humanware, and orgaware [28]. Hardware in science learning can be understood as experimental tools used in the science learning process in the classroom. Software is a program that can run the hardware used. Infoware or material is a concept that can be displayed with the hardware. Humanware is human resources who can run and use the hardware. Orgaware is a management organization device that can run learning technology in a learning process with certain materials. The rapid development of technology in the current digital era has given rise to a lot of digital learning technology. These developments will certainly have an impact on the world of education. The learning process must of course adapt to changes. The presence of ICT (Information, Communication, and Technology) in the world of education, requires students to be creative, innovative, think critically and metacognitively so that students have the ability to communicate and work collaboratively (in groups) with the hope that the knowledge and skills gained can be used as provisions for life in society. which has both local and global character and can be personally and socially accountable [29].

ICT-based science learning technology (Information, Communication, and Technology) is very easy to find on the internet. Science learning simulation or virtual laboratory-based learning, for example by accessing PhET Colorado [30]. Various kinds of experiments or simulations can be found on the site. Other applications that are more than virtual laboratory activities by integrating hand on activities with digital applications are tracker analysis, stellarium, and visual analyzer. The results of work in the laboratory are recorded in video form and inputted into the application so that they are able to produce various kinds of analytical graphs related to physical quantities [31]. Several example of ICT-based science learning technology can see on Fig 2.



(a) (b)

FIGURE 2. Example of a digital-based simulation application (a) PhET Colorado (b) Tracker analysis

Based on some of the descriptions above, it can be concluded that digital-based science learning technology is basically information and communication technology. The technology is an inseparable combination and has a broad understanding of all activities related to processing, manipulating, processing, and transferring or transferring information between media. The functions of technology in science learning include tools for both simulations and experiments in virtual laboratories, sources of knowledge, as well as materials and aids for learning (literacy).

CONCLUSION

Based on the results of the study, it can be concluded that science learning oriented to the development of higher order thinking skills is learning based on a scientific approach covering aspects of observing, asking, experimenting, associating, and communicating which are fully both basic and integrated in science process skills. As for the digital era, science learning that is oriented to the development of higher-order thinking skills is applied by using digital-based technology such as simulations and virtual laboratories to make science lessons well understood and able to improve students' higher-order thinking skills. The simulations and virtual laboratory activities are integrated into the science learning model as a support for learning based on a scientific approach.

REFERENCES

1. S.I. Jessani, J. Educ. Educ. Dev. **2**, 79-87 (2015).
2. O. Akinoglu and R.O. Tandogan, Eurasia J. Math. Sci. Technol. Educ. **3**, 71-81 (2007).
3. Faisal and S.N. Martin, Asia-Pac. Sci. Educ. **5**, 1-29 (2019).
4. A.H. Wahid and R.A. Karimah, Modeling **5**, 82-98 (2018).
5. I.B.P. Aryana, Pembelajaran untuk Meningkatkan Kompetensi 4C (Communication, Collaboration, Critical Thinking Dancreative Thinking) untuk menyongsong Era Abad 21, Konferensi Nasional Matematika dan IPA (Universitas PGRI Banyuwangi, Banyuwangi, 2019), pp. 1–13.
6. D. Rosana, J. Penelit. dan Eval. Pendidik. **13**, 268-284 (2013).
7. S. Dimyati and A. Said, How to Teach Science for Elementary Gifted Students a Case Study Done at Cgs Cianjur in Indonesia, ICEL Proceedings (Universitas Bandar Lampung, Lampung Indonesia, 2014), p. 4.
8. Wangsa, G. N. Arya Surya, N. Dantes, and I. W. Suastra, PENDASI: Jurnal Pendidikan Dasar Indonesia **5**, 139-150 (2021).
9. Windadai, *Pembelajaran Daring IPA Lebih Bermakna dengan Project Based Learning* (Jawa Pos, Central Java, 2021), pp. 2-3.
10. A. Pratiwi, *Tingkatkan Literasi Digital di Masa Pandemi* (Dirjen Aptika Kominfo, Jakarta, 2020), p. 1.
11. A. Irhandayaningsih, Anuva **4**, 231-240 (2020).
12. D. Bawden, *Origins and Concepts of Digital Literacy, in: Digital Literacies: Concepts, Policies and Practices* (Peter Lang Publishing, New York, USA, 2008).
13. T. Tafonao, S. Saputra, and R. Suryaningwidi, Indones. J. Instr. Media Model **2**, 89-100 (2020).
14. R. Habibah, U.H. Salsabila, W.M. Lestari, O. Andaresta, and D. Yulianingsih, Trapsila J. Pendidik. Dasar **2**, 1-13 (2020).
15. L.S. Sahelatua and L. Vitoria, J. Ilm. Pendidik. Guru Sekol. Dasar **3**, 131-140 (2018).
16. R.K. Sawyer, Optimising Learning: Implications of Learning Sciences Research, CERI International Conference (OECD, Paris, 2008), pp. 45–65.
17. Kemdikbud, *Undang-undang Sistem Pendidikan Nasional*, (Kemdikbud, Jakarta, 2003), p. 4.
18. E.L. Chiappetta and T.R. Koballa, *Science Instruction in The Middle and Secondinary Schools Developing Fundamental Knowledge and Skills* (Pearson Education Inc., New Jersey USA, 2006), pp. 73-74.
19. R. Mickens and C. Pattrson, Ga. J. Sci. **74**, 1-5 (2016).
20. V.M. Christine, *The Nature of Science and the Scientific Method* (The Geological Society of America, USA, 2015).
21. A. Kurniawati, J. Sci. Educ. Res. **5**, 16 (2021).
22. M.M. Baharom, N.A. Atan, M.S. Rosli, and S. Yusof, Int. J. Interact. Mob. Technol. **14**, 95-95 (2020).
23. M.N. Sheeba, Educ. Confab **1**, 1-10 (2013).
24. R.J. Rezba, *Learning and Assesing Science Process Skill* (Kendall/ Hunt Publishing Company, Amerika Serikat, 2002).
25. M. Yaumi, *Media dan Teknologi Pembelajaran* (Prenada Media, Jakarta, 2018), pp 20-21.
26. R. Tavares, R. Marques Vieira, and L. Pedro, Educ. Sci. **11**, 79 (2021).
27. F. Firmadani, *Strategi dan Implementasi Pendidik. Karakter. Pada Era Revolusi Ind. 40* (Universitas Mercubuana Yogykarta, Yogyakarta, 2020), pp. 93–97.
28. Supriyadi, *Kurikulum Sains dalam Proses Pembelajaran Sains* (Pustaka Tempelsari, Yogyakarta, 2007), pp. 43-45.
29. N. Khasanah, *Konservasi dan Pemanfaatan Sumber Daya Alam* (FKIP Universitas Negeri Sebelas Maret, Surakarta, 2015), pp. 270–277.
30. D.R. Rizaldi, A.W. Jufri, and J. Jamal, J. Ilm. Profesi Pendidik. **5**, 10-14 (2020).
31. M. Habibbulloh and M. Madlazim, J. Penelit. Fis. dan Apl. JPFA **4**, 15-22 (2014).