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Research Article

Implementation of integrated science curriculum: a critical review of the literature

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Abstract

The current trend in science learning leans more towards interdisciplinary (integrated) learning. Before 1989, several studies reviewed articles related to integrated science. However, research discussing articles on integrated science from 1996 until the present day is not yet available. The purpose of this study was to review 36 empirical research articles on integrated science published from 1996 to 2019. Most of these articles were taken from Scopus-indexed journals. The research approach used was a qualitative research design. The results of this study show that integrated science has been implemented in various countries. Nonetheless, the implementation of integrated science did not prove out as successful as expected. Students' perception of integrated science is difficult, boring, uninteresting, and abstract. There are several issues in the implementation of integrated science learning: the inconsistency of teachers' educational backgrounds with integrated science, as well as underdeveloped textbooks and curriculum. Implementation of integrated science learning is effective for improving student skills.

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Introduction

Integrated science is a science that integrates several different disciplines (Biology, Microbiology, Ecology, Physics, Chemistry, Earth Science, and Astronomy) (Hewitt, Lyons, Suchocki, & Yeh, 2013). UNESCO has several reasons to introduce integrated science in various countries as an element in basic education. Some of these reasons are: (1) integrated science learning at primary and secondary levels can provide a strong basis for students to learn more integrated science or specialist subjects; (2) the development of modern science leads to the interdisciplinary nature of science (Oludipe, 2012; Olarewaju, 1994). Frey (1989) states that integrated science aims to combine concepts, perspectives, and methods from various scientific disciplines to interpret scientific phenomena in everyday life. The rationale for an integrated curriculum is to show how interdisciplinary knowledge is related to one another (Yager & Lutz, 1994). The rationale explains that science education reform should emphasize what and how to teach the content of all science (Physics, Biology, Chemistry, and Earth Science). Based on these grounds, many educators support the implementation of an integrated curriculum (Zhou & Kim, 2010).

Researches about integrated science have been carried out in various countries. Some studies have investigated the implementation of integrated science (Sun, Wang, Xie, & Boon, 2014; Oludipe, 2012), students' perceptions of integrated science (Zhang & He, 2012; Ogunkola & Samuel, 2011), and problems related to integrated science (Otarigho & Oruese, 2013; Harrell, 2010; Nampota, 2008; Zhou, & Botha, 2008; Green & Osah-Ogulu, 2003). Besides, there are other studies inquired into the influence of integrated science learning on students', preservice science teachers' and teachers' understanding of integrated science concepts (Parmin, Nuangchalerm, & El Islami,

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2019; Uyar, Demirel, & Doganay, 2018; Rubini, Ardianto, Pursitasari & Hidayat, 2018; Wei, 2018; Putica & Trivić, 2017; Thang & Koh, 2017; An, 2017; Setiawan, 2015; Cervetti, Barber, Dorph, Pearson & Goldschmidt; 2012). Some researches were also used to measure the influence of integrated science learning on students' skills. These skills include scientific work independence (Parmin, Sajidan, Ashadi, Sutikno, & Fibriana, 2017), students' experience (Ebersole & Kelty-Stephen, 2017), scientific literacy (Ardianto & Rubini, 2016), students' responses (Van Hecke, Karukstis, Haskell, McFadden & Wettack, 2002), and students' level of satisfaction and self-confidence (Beichner et al. 1999).

More studies with research and development methods are used to develop integrated science instruments. Some of these studies are: (1) On the topic of energy explained in three subjects: Physics, Chemistry, and Biology (Opitz, Neumann, Bernholt & Harms, 2017); (2) Integrated science learning media based on science-edutainment (Taufiq, Dewi & Widiyatmoko, 2014); (3) Integrated science learning tools using a humanistic approach assisted with props (Widiyatmoko, 2013); (4) Inquiry-based integrated science worksheets (Putri & Widiyatmoko, 2013); (5) and science learning using Problem Base model in the lesson study (Rahayu, Mulyani & Miswadi, 2012). Also, there are several studies reviewing journal articles on integrated science; these articles were published in 1977, 1979, 1985, and 1989. That being said, the articles mentioned above are obsolete; the results are not compliant to the current development of integrated science. The difference between this study and the previous research is the period time in which the articles discussed were published: the previous studies reviewed articles from the 1960s to 1980s (Brown, 1977; Haggis & Adey, 1979; Hacker & Rowe, 1985; Frey, 1989); meanwhile, the articles reviewed in this study were published through 1996 to 2019. Therefore, this study offers results that illustrate the most current development of integrated science. Moreover, a more comprehensive explanation is presented. The are several important key points in this research. We elaborate the definition of integrated science, the history of the implementation of integrated science, countries that have implemented integrated science to date, the investigation of the implementation of integrated science, the effectiveness of integrated science learning, the integration of science, and the advantages and disadvantages of integrated curriculum models.

Problem of Study

This research is essential for researchers of science education that encounter difficulties in finding literature on integrated science because the number of journals is limited. Based on interviews with several educators of science education in Indonesia, many of them do not have a profound understanding of integrated science. Consequently, this research was conducted to provide a comprehensive explanation of integrated science for researchers, lecturers, preservice science teachers, science teachers, and other stakeholders. Another underlying reason for this research is the fact that learning trends these days lean more towards interdisciplinary (integrated) learning, which connects one discipline with another. Ultimately, the purpose of this study is to review empirical research articles related to integrated science published from 1996 to 2019. In this study, there are seven main questions used to guide the analysis of the literature.

- What is integrated science?
- What is the history of the implementation of integrated science?
- Which countries have implemented integrated science?
- How is the implementation of an integrated science curriculum?
- How is the effectiveness of integrated science learning?
- How to integrate science?
- What are the advantages and disadvantages of learning with integrated curriculum models?

Method

Research Design

The research approach used was qualitative research design (Creswell, 2008). The articles analyzed amounted to 36 articles published from 1996 to 2019. Most articles were selected from Scopus indexed reputable international journals (not from seminar proceedings); this is due to the high quality of Scopus-indexed articles.

Participants/ Sample

The sample of the research was taken from 36 international journals. Selected articles consist of 30 articles (83.33%) indexed by Scopus and six articles (16.67%) indexed by other institutions. 30 Scopus indexed articles (83.33%) are divided into quartile 1 (Q1), quartile 2 (Q2), quartile 3 (Q3), and quartile 4 (Q4). Q1 consists of 10 articles (27.77%); Q2 consists of five articles (13.89%); Q3 consists of 12 articles (33.33%), and Q4 consists of three articles (8.33%). Meanwhile, the other six articles (16.67%) were indexed by Copernicus, ProQuest, Google Scholar, etc. The results of the reviewed journals can be seen in table 1.

Table 1.

The result of journals searched for review

No	Name of journal	Total of Articles	Year	Indexed By
1.	International Journal of Science Education	4	1996, 2009, 2012, 2014	Scopus (Q1)
2.	Research in Science Education	2	2000, 2018	Scopus (Q1)
3.	Journal Of Research In Science Teaching	1	2012,	Scopus (Q1)
4.	Studies in Science Education	1	2002	Scopus (Q1)
5.	Journal of Education for Teaching	1	2003	Scopus (Q1)
6.	ZDM Mathematics Education	1	2017	Scopus (Q1)
7.	EURASIA Journal of Mathematics Science and Technology Education	1	2017	Scopus (Q2)
8.	Journal of Chemical Education	1	2002	Scopus (Q2)
9.	Journal of Baltic Science Education	2	2017, 2018	Scopus (Q2)
10.	American Journal of Physics	1	1999	Scopus (Q2)
11.	Journal of Turkish Science Education	1	2016	Scopus (Q3)
12.	Canadian Journal of Science, Mathematics and Technology Education	1	2010	Scopus (Q3)
13.	African Journal of Research in Mathematics, Science and Technology Education	1	2008	Scopus (Q3)
14.	Action Learning: Research and Practice	1	2017	Scopus (Q3)
15.	Jurnal Pendidikan IPA Indonesia (Indonesian Journal of Science Education)	8	2012, 2013, 2013, 2014, 2015, 2016, 2017, 2018	Scopus (Q3)
16.	Psychology Learning & Teaching	1	2017	Scopus (Q4)
17.	Journal for the Education of Gifted Young Scientists	1	2019	Scopus (Q4)
18.	Africa Education Review	1	2007	Scopus (Q4)
19.	European Scientific Journal	1	2013	Copernicus, EBSCO
20.	Spring journal	1	2010	Google Scholar, Mendeley
21.	World Journal of Education	1	2011	Copernicus, google scholar
22.	International Journal of Social Sciences and Education	1	2012	EBSCO, ERA, google scholar.
23.	International Journal of Education and Research	1	2013	Google scholar, research gate
24.	Techno LEARN: An International Journal of Educational Technology	1	2013	Google Scholar
	Total	**36**		

Data Collection

Data collection in this study uses research procedures developed by researchers. The procedures in selecting articles for this study were: (1) searching for articles on search engines such as https://scholar.google.com and https://www.google.com, on reputable journal website by looking at the archived sections respectively, and on reputable journal publisher websites such as Springer, Taylor and Francis Group, Sage, Emerald, Science Direct, Cambridge, etc.; (2) entering the keywords of "integrated science" or "integrated science curriculum"; (3) reading the title, abstract as well as the content, the related articles were downloaded, and the unrelated ones were dismissed; (4) understanding the selected article comprehensively starting from the abstract, introduction, method, results, and discussion, conclusions; (5) reviewing the selected articles; (6) analyzing the results of the reviewed articles based on the research problem; (7) writing the results of the reviewed articles for the discussion of this critical review.

Data Analysis

Data from the review results of the articles were analyzed descriptively. Based on the search results on Google, journal websites, and publisher websites, researchers obtained more than 100 reputable articles. However, after the perusal of the contents, most of the articles are not related to integrated science. Besides, most of the dismissed articles, although related to integrated science, were published before 1996. Most of the rejected articles are also from seminar proceedings (not a reputable international journal). After carefully selecting the articles, researchers selected 36 international journals deemed suitable for analysis. In the discussion section, this article also elaborates several Scopus indexed journals or proceedings as supporting data to corroborate the main data. The supporting articles were also used for the writing of this article to provide a more comprehensive and detailed explanation.

Results

We present the results of the 36 journal analyzes into five tables. The tables will explain the distribution of study results based on integrated science problems, distribution of study results based on the effectiveness of the use of integrated science in students, distribution of study results based on the effectiveness of the use of integrated science in teachers, distribution of study results related to educational research and development in integrated science, and distribution of other study results related to integrated science. The summary of the analysis of 36 journals related to integrated science can be seen in table 2 to table 6. Distribution of study results based on integrated science problems can be seen in table 2.

Table 2.

Distribution of study results based on integrated science problems

No	Study	N/Grade Level	Research Approach	Results
1.	Zhang and He (2012)	27 undergraduate students and 25 alumni	Qualitative	Students' perceptions of the implementation of integrated science programs in several universities were still low.
2.	Ogunkola and Samuel (2011)	200 lower secondary school students and 30 teachers	Quantitative	Middle school students found integrated science subjects difficult, boring, and uninteresting. The concepts of science were thought to be abstract.
3.	Sun, Wang, Xie, and Boon (2014)	36 science teachers	Qualitative	The implementation of the integrated science curriculum at the secondary level did not prove out as successful as expected.
4.	Otarigho and Oruese (2013)	360 secondary school students	Qualitative	The government should employ specialists in integrated science.
5.	Oludipe (2012)	Secondary schools students and integrated science teachers	Quantitative	The implementation of integrated science in Nigeria was still not maximized.
6.	Harrell (2010)	93 science teachers	Quantitative	Most teachers in Texas came from a single-field educational background (Physics/Biology only). They were not from an integrated science department.
7.	Nampota (2008)	Documentation of the junior and senior integrated science curriculum	Qualitative	The integrated science curriculum that was implemented had not yet succeeded in achieving its learning goals as a strong foundation for higher education level (university).

No	Study	N/Grade Level	Research Approach	Results
8.	Zhou and Botha (2008)	44 integrated science teachers.	Quantitative	Survey results show that the availability, suitability, and use of integrated science teaching materials in schools still needed to be reworked.
9.	Green and Osah-Ogulu (2003)	30 teachers of integrated science	Qualitative	Teachers from integrated science tend to be strong in the competency category and weak in the pedagogic category.

Based on table 2 shows that there are some problems when the implementation of integrated science in various countries. The implementation of integrated science is still not as successful as expected. The competence of teachers in teaching integrated science is still low because most teachers who teach integrated science are not from integrated science majors. Also, several studies investigate the effectiveness of the use of integrated science as an approach to learning. Distribution of study results based on the effectiveness of the use of integrated science in students can be seen in Table 3.

Table 3.
The Distribution of Study Results is Based on the Effectiveness of the Use of Integrated Science in Students

No	Study	N/Grade Level	Research Approach	Results
10.	Parmin, Nuangchalerm, and El Islami (2019)	58 preservice science teachers	Qualitative	Learning with Science Integrated Learning (SIL) was effective for the development of science content.
11.	Uyar, Demirel, and Doganay (2018)	25 preservice teachers	Qualitative	Learning with interdisciplinary curriculum had a positive outcome on preservice teachers' understanding and knowledge of the nature of science.
12.	Parmin, Sajidan, Ashadi, Sutikno, and Fibriana (2017)	86 preservice science teachers	Quantitative	Integrated science learning improved the scientific work independence of preservice science teachers.
13	Ebersole and Kelty-Stephen (2017)	19 upper-class students	Quantitative	Students benefited and experienced greatly after integrated science learning.
14.	Putica and Trivić (2017)	258 students of high school	Quasi-experimental	Experiments in the classroom on the topic of digestion with an interdisciplinary teaching approach resulted in better conceptual understanding compared to the control class.
15.	Thang and Koh (2017)	227 secondary school students	Quantitative	Integrated science modules increased students' confidence and improved skills related to information analysis, time management, and the use of information communication technology.
16.	Ardianto and Rubini (2016)	70 secondary school students	Quantitative	Integrated science learning with guided discovery and problem base model improved scientific literacy.
17.	An (2017)	28 elementary preservice teachers	Qualitative	Learning with an interdisciplinary approach improved the ability to connect one discipline to another (interdisciplinary knowledge).
18.	Çinar, Pirasa, Uzun, and Erenler (2016)	32 preservice science teachers	Qualitative	Interdisciplinary approaches guided preservice science teachers to be able to connect natural science to other disciplines.
19.	Setiawan (2015)	40 undergraduate students	Quantitative	There was a cognitive and pedagogical improvement in integrated science courses with simulation methods.

No	Study	N/Grade Level	Research Approach	Results
20.	Alake and Ogunseemi (2013)	450 secondary school students	Quantitative	Integrated science learning using scaffolding strategies was proven to be useful in improving academic achievement compared to traditional methods of learning.
21.	Agoro & Akinsola (2013)	294 preservice science teachers	Quantitative	Preservice science teachers' achievements and science process skills in integrated science could be increased with Reflective-Reciprocal Peer Teaching Strategies.
22.	Zhou and Kim (2010)	77 preservice teachers	Qualitative	Learning with an integrated method could increase preservice teachers' understanding of an integrated curriculum.
23.	Van Hecke, Karukstis, Haskell, McFadden & Wettack (2002)	36 undergraduate students	Quantitative	Learning with an interdisciplinary laboratory approach resulted in positive responses compared to traditional learning.
24.	Beichner et al. (1999)	78 physics student	Mixed-Method	Classes with an integrated science curriculum generated a high level of satisfaction and confidence.

Based on table 3 shows that the use of integrated science in learning has benefits for students. The use of integrated science can improve science content, knowledge of the nature of science, the scientific work independence, scientific literacy, satisfaction, confidence, and the ability to connect one discipline to another (interdisciplinary knowledge). Besides, several other studies aim to investigate the effectiveness of the use of integrated science in teachers. Distribution of study results based on the effectiveness of the use of integrated science in teachers can be seen in table 4.

Table 4.
The Distribution of Study Results is Based on the Effectiveness of the Use of Integrated Science in Teachers

No	Study	N/Grade Level	Research Approach	Results
25.	Rubini, Ardianto, Pursitasari, and Hidayat (2018)	25 science teacher	Qualitative	The developed training program improved teachers' knowledge of scientific literacy, integrated science learning concepts, and designing integrated science learning.
26.	Wei (2018)	Six science teachers	Qualitative	During the implementation of integrated science, there were developments in science teachers' skills and understanding: updated science content knowledge, reshaped conception of science teaching, increased collaboration with teachers, and built relationships with students.
27.	Cervetti, Barber, Dorph, Pearson, Goldschmidt (2012)	94 elementary school teachers	Quantitative	Groups learning with integrated approach reaped better results in science understanding, science vocabulary, and science writing.
28.	Lang and Olson (2000)	22 teachers	Quantitative	Integrated science teaching can develop new conceptual structures.

Based on table 4 explains that the use of integrated science is effective for improving various teacher' skills. Some teacher skills can be enhanced by the use of integrated science such as scientific literacy, science content knowledge, designing integrated science learning, collaboration with other teachers, built relationships with students, and developing new conceptual structures. Furthermore, the distribution of study results related to educational research and development in integrated science can be seen in Table 5.

Table 5.

Distribution of Study Results Related to Educational Research and Development in Integrated Science

No	Study	N/Grade Level	Research Approach	Results
29.	Opitz, Neumann, Bernholt, and Harms (2017)	752 students grade 6, 8, and 10	Educational research and development	Producing integrated science instruments on the topic of energy in three different disciplines: Physics, Chemistry, and Biology.
30.	Taufiq, Dewi, and Widiyatmoko (2014)	38 secondary school students and science teachers	Educational research and development	The study generated integrated learning media based on science-edutainment on the topic of conservation. Integrated science learning outcomes increased significantly.
31.	Widiyatmoko (2013)	26 secondary school students and two science education lecturer	Educational research and development	Producing a valid integrated science learning device using a humanistic approach assisted with props.
32.	Putri and Widiyatmoko (2013)	Eight secondary school students	Educational research and development	It was generating valid inquiry-based integrated science worksheets. The implementation of the worksheet was effective for learning.
33.	Rahayu, Mulyani, and Miswadi (2012)	Secondary school students	Educational Research and Development	Integrated science learning using problem-based learning models through lesson study improved scientific work skills and student learning outcomes.

Based on Table 5 shows that some research related to integrated science uses a research approach. The research approach is educational research and development. These studies develop worksheets, instruments, learning media, and others. The results showed that the instrument developed had a positive impact on students. Also, the distribution of other study results related to integrated science can be seen in Table 6.

Table 6.

Distribution of other Study Results Related to Integrated Science

No	Study	N/Grade Level	Research Approach	Results
34.	Wei (2009)	Four informants and curriculum documents	Qualitative	There are two models applied in junior secondary schools in China: integration within science subject and integration beyond science subject.
35.	Venville, Wallace, Rennie, & Malone (2002)	Some literature	Qualitative	The integrated curriculum used is not necessarily better than the subject-based curriculum.
36.	Whiteley (1996)	Some integrated science textbooks	Qualitative	In the 1970s and late 1980s, integrated science books used at Jamaican high schools showed that some changes had taken place in the direction of 'gender fairness.'

Table 6 shows that several qualitative studies analyze literature curriculum documents and integrated science textbooks as material for their research. The results of the study explain that there are two models applied in China (integration within science subject, and integration beyond science subject), explanation related to gender fairness in several integrated science books in Jamaican. Other research results explain that the use of an integrated curriculum is no better than the subject-based curriculum.

Table 2 to table 6 shows that the sample used consisted of various levels. Some of the samples are elementary school students, secondary school students, senior high school students, undergraduate students, preservice science teachers, elementary preservice teachers, science teachers, alumni, informants, and lecturers. The research approach used includes qualitative research design, quantitative research design, mixed-method, as well as educational research and development.

Discussion

This research explains comprehensively the review of the literature addressing several points: (1) what is integrated science?; (2) what is the history of the implementation of integrated science?; (3) which countries that have implemented integrated science?; (4) how is the implementation of an integrated science curriculum?; (5) how is the effectiveness of integrated science learning?; (6) how to integrate science? (7) what are the advantages and disadvantages of learning with integrated curriculum models?

What is integrated science?

Hewitt, Lyons, Suchocki, and Yeh (2013) explain that integrated science is a science that integrates a variety of different disciplines (Biology, Chemistry, Physics, Microbiology, Ecology, Earth Science, and Astronomy). Haggis and Adey (1979) state that the first integrated science course mostly only integrated Physics, Chemistry, Biology, most excluded Earth and Space Science. Integrated science aims to combine concepts, perspectives, and methods from various scientific disciplines to interpret scientific phenomena in everyday life (Frey, 1989). The rationale for an integrated curriculum is to show how interdisciplinary knowledge is related to one another (Yager & Lutz, 1994).

Haggis and Adey (1979) add that the scope of science integration can be divided into three classifications: (a) two science disciplines, (b) three science disciplines, and (c) two more sciences plus at least one non-science subject.

a. Two science disciplines

Two science disciplines are the integration of two different subjects, such as Physics and Biology, Physics and Chemistry, or Biology and Chemistry. One example of a topic that can be explained using two different disciplines is Newton's Law: in Physics and Biology. In Physics, Newton's First Law explains the concept of inertia $(\sum \vec{F} = 0)$. Newton's Second Law explains the relationship between net force, acceleration and the mass of an object $(\sum \vec{F} = m\vec{a})$. Newton's Third Law explains that action and reaction forces ($\vec{F}_{12} = -\vec{F}_{21}$). In Biology, Newton's Law can be related to animal locomotion as well as the similarity between a wingsuit flyer and a flying squirrel (Hewitt, Lyons, Suchocki & Yeh, 2013; Winarno et al. 2019).

b. Three science disciplines

Three science disciplines are the integration of three different subjects, such as Biology, Physics, and Chemistry. One example of a topic that can be explained using three different disciplines is Energy in Biology, Physics, and Chemistry. In Biology, the topic of energy is related to glucose (energy for life). In Physics, it can be linked to potential energy $(EP = mgh)$, kinetic energy $\left(EK = \frac{1}{2}mv^2\right)$ and mechanical energy $(EM = EP + EK)$. In Chemistry, the topic of energy is related to the conversion of energy in fossil fuels to Heat (Trefil & Hazen, 2010; Hewitt, Lyons, Suchocki & Yeh, 2013).

c. Two more sciences plus at least one non-science subject.

One example of this scope is the integration of Physics, Biology, Chemistry, Technology, and Mathematics (Haggis & Adey, 1979). One topic that can be explained is Heat. The topic can be explained in Physics, Chemistry, Biology, Astronomy, Geology, and Technology. In Physics, Heat can be related to formulas of heat transfers such as conduction [$P = \frac{Q}{t} = \frac{kA(T_H - T_C)}{L}$], convection [$Q = hA(T_H - T_C)$ and radiation ($P = \sigma\varepsilon T^4 A$) (Halliday, Resnick & Walker, 2011). In Biology, Heat can be related to all living things grow old and die as molecular defects in cells increase. In Chemistry, it can be connected to entropy, the release of chemical energy of gasoline by burning. In Geology, Earth's interior receives heat energy from volcanoes. In technology, the Heat is existent in home insulation and thermometers (Trefil & Hazen, 2010; Hewitt, Lyons, Suchocki & Yeh, 2013).

What is the history of the implementation of integrated science?

In 1967, the first international symposium on integrated science education was held in Lausanne, Switzerland. The symposium was entitled "Coordination of the Teaching of Mathematics and Physics" (Frey, 1989). The United Nations Educational Scientific and Cultural Organization (UNESCO) proposed a program to develop and improve science education by exchanging information from various countries. UNESCO launched "The Teaching of Basic Science" in 1967. Each discipline of Physics, Biology, Chemistry, and Mathematics Education had its published articles and papers of several volumes on new trends in materials, content, and methods (Richmond, 1971).

In 1968, UNESCO collaborated with the Committee on the Teaching of Science (CTS) and the International Council of Scientific Unions (ICSU) to hold an international conference on integrated science education in Droujba, Bulgaria. Throughout the conference, 15 conclusions and recommendations in the form of guidelines and ideas on integrated science education were produced (UNESCO, 1990). These ideas and guidelines became the source of ideas, new initiatives, and approaches to science education. In 1973, UNESCO—in collaboration with ICSU, CTS, and the University of Maryland—held an international conference in Maryland, USA. The conference discussed teacher training and education issues around integrated science.

Furthermore, another international symposium—held in Oxford, England, in 1975—discussed the assessment and evaluation of integrated science education. UNESCO and the International Council of Associations for Science Education (ICASE) also held an international conference in Nijmegen, the Netherlands in 1978. The discussion revolved around the development of integrated science education. The articles from 1973, 1975, and 1978 conferences were published respectively in the proceedings of UNESCO "New Trends in Integrated Science Teaching" Volume III, Volume IV, and Volume V (UNESCO, 1990).

Following these conferences, UNESCO published articles and papers entitled "New Trends in Integrated Science Teaching," consisting of Volumes I to Volumes VI. UNESCO published Volume I in 1971; Volume II in 1973: Volume III in 1974; Volume IV in 1977; Volume V in 1979; and Volume VI in 1990. The articles in Volume I and Volume II analyzed trends in rapidly developing fields in the world. Volume III is on teacher education. Volume IV examined the evaluation of integrated science education. Volume V elaborated on the development of integrated science education in the previous ten years, the 1980s and beyond (Cohen, 1977; Reay, 1979). Volume VI explained the general review of trends—regional and national trends in integrated science teaching and examples of the implementation of integrated science teaching (UNESCO, 1990).

UNESCO played a major role in the introduction of integrated science. Since the first international symposium in 1967, integrated science has continued to develop in various countries. The development of integrated science is proven by several studies published from the 1970s to the 2000s (Brown, 1977; Hacker and Rowe, 1985; Lang & Olson, 2000; Harrell, 2010). The integrated science curriculum is still being implemented in various countries to this day. This is proven by the articles on integrated science published in the last three years (Putica & Trivić, 2017; Rubini, Ardianto, Pursitasari, & Hidayat, 2018; Opitz, Neumann, Bernholt, & Harms, 2017; Uyar, Demirel & Doganay, 2018; Parmin, Nuangchalerm, & El Islami, 2019). The results of the conference and research, it can be concluded that integrated science began to be introduced in 1967 and is still being implemented in various countries to the present day.

Which countries have implemented integrated science?

According to UNESCO (1990), integrated science was first introduced in various countries through various international seminars. The United Kingdom was one of the first countries to introduce integrated science (Nuffield Combined Science and Scottish Integrated Science). Also, the United States and Canada are also included in the list. Thus, the pioneering countries of the introduction of integrated science are the United Kingdom, the United States, and Canada. Integrated science also began to be implemented in several other European countries such as the United Kingdom, Belgium, and the Netherlands. For example, Belgium first conducted an integrated science course in senior high schools (grades 10 to 11) in 1978. Integrated science was first introduced in the Netherlands in 1983. Curriculum innovation with integrated science was also offered. The proposal offered at that time was the integration of traditional disciplines.

Asian countries that have implemented integrated science are Brunei, Singapore, Malaysia, Hong Kong, China, India, Indonesia, the Philippines, Singapore, and Thailand. Integrated science began to develop in Asian countries five decades ago. This development was shown by the shift from traditional science (grades 7 to 9) to integrated science in Brunei, Singapore, Malaysia, and Hong Kong in the 1970s. In 1970, Brunei first tested integrated science in two schools: English Medium (SOASC) and Malay Medium (SMJA). In 1972, all schools in Brunei had changed from general science to integrated science (UNESCO, 1990). Different countries implement integrated science differently: some in primary school, secondary level, or both. This different implementation rests upon the education policies of each country. For example, in Indonesia, the initial application began in primary schools (Grade 4 to 6); at that time, integrated science was not yet taught in secondary schools. Indonesia started to implement integrated science in secondary schools in 2013. Meanwhile, China has implemented an integrated science curriculum since the mid-1980s in secondary school students (grades 7-9) (Wei, 2009).

UNESCO (1990) adds that integrated science was also implemented in several countries in Africa. The list includes Nigeria, Gambia, Botswana, Lesotho, Jamaica, and Swaziland (UNESCO, 1990). Jamaica incorporated an integrated science curriculum in the 1970s (Whiteley, 1996). It started at primary and secondary levels. One integrated science book that was introduced at the secondary level at that time was Science for the Seventies published in 1971 (UNESCO, 1990).

In 1987/1988, the Science Education Center of Ain Shams University, Cairo, conducted a survey of comparative studies in four Arab States. The results show that the Arab States began to implement integrated science at the lower secondary level (grades 7 to 9); the said states are Saudi Arabia, Qatar, Jordan, and the Arab Republic of Egypt. Also, integrated science teaching was introduced in Kuwait, specifically at primary level (grade 1 to 4), intermediate (grade 5 to 8) and secondary (grade 9 to 12) (UNESCO, 1990).

Countries that have implemented integrated science on the American continent are the United States, Canada, and Columbia (UNESCO, 1990; Lang & Olson, 2000; Harrell, 2010). Not only in Europe, Asia, Africa, and Arab states, but Australia, Papua New Guinea, and New Zealand have also incorporated integrated science in their school curriculum. It is stated that the implementation of integrated science in New Zealand comes in several levels of science education: primary science (5 to 10-year-olds), secondary science (11 to 16-year-olds), and senior science (16 to 18-year-olds) (UNESCO, 1990). It can be concluded that integrated science has been implemented in various countries. The list of countries that have implemented an integrated science curriculum can be seen in Figure 1.

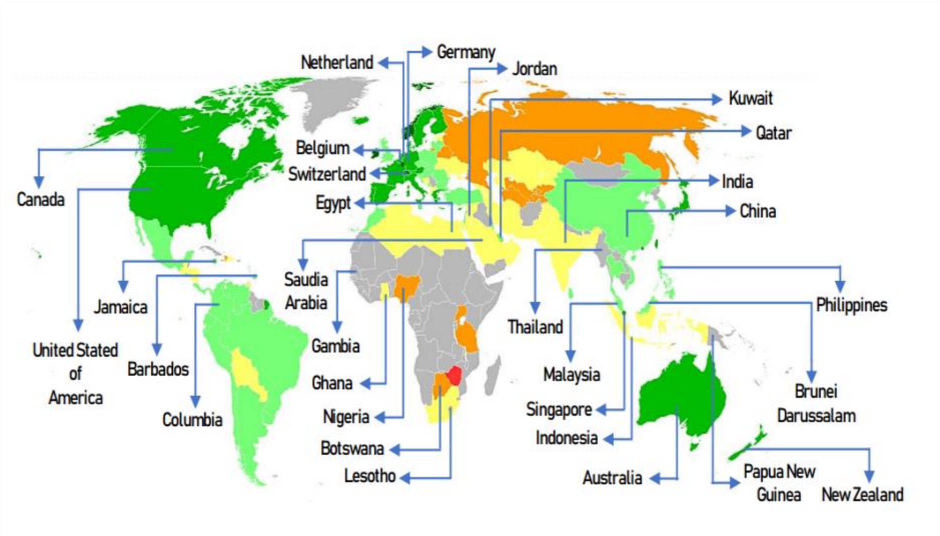


Figure 1.
Countries Implement Integrated Science Curriculum

How is the implementation of an integrated science curriculum?
An integrated science curriculum started to be implemented in various countries five decades ago. However, based on the results of the analysis of international journals, it is stated that the implementation still encounters many problems. The results of several studies support this statement. The implementation of the integrated science curriculum at junior secondary level in China did not prove out as successfully as expected (Sun, Wang, Xie & Boon, 2014); the same dilemma was also faced in Nigeria (Oludipe, 2012). These facts are in line with the research done by Nampota (2008), stating that the integrated science curriculum has not yet succeeded in achieving the learning objectives as a strong foundation for higher education (university). This unsuccessful implementation is caused by several problems of teachers, students, lecturers, preservice science teachers, or other stakeholders.

Teachers possess an important role in integrated science learning (Rahayu, Mulyani, & Miswadi, 2012). However, it is found that in several countries, many educators experience problems in teaching integrated science. Some previous studies prove that integrated science learning in the classroom depends greatly on the teacher (teacher-centered), hence limiting students' participation. In teaching integrated science, teachers still emphasize one subject (within-subject knowledge) instead of integrating multiple subjects (cross-subject knowledge). Also, teachers are not yet considered to be competent enough to design and delivering scientific material, scientific inquiry, scientific experiments, technology, and society content (Sun, Wang, Xie & Boon, 2014). Most teachers in Texas come from a single-field subject degree (Physics or Biology only); they are not from integrated curriculum departments; thus, teachers require additional training to teach the integrated curriculum. Presently, many teachers have not yet participated in such specialized training. Based on a study conducted by Harrel (2010), 26% of teachers have not received training in Chemistry; 45.7% in Physics; 48.9% in Earth Science. These results are in line with the findings of another study that investigated 25 science teachers. The results indicate that one of the weaknesses of science teachers in secondary schools is their inability to develop integrated science learning (Rubini, Ardianto, Pursitasari & Hidayat, 2018). Green and Osah-Ogulu (2003) also investigated integrated science teachers; their findings show that teachers from integrated science tend to be strong in the competency category and weak in the pedagogic category. Based on the study of literature, most of the problems that occur are the unmet standards and quality of teachers in integrated science teaching. Unfortunately, teachers carry an essential role in the success of science learning.

Problems faced by teachers consequently affect students' perceptions of integrated science subjects. Some previous studies state that students find integrated science difficult, boring, and uninteresting. This is due to students thinking of science as an abstract subject (Ogunkola & Samuel, 2011). This fact is supported by several other studies, finding that students' attitudes on the implementation of integrated science are still considered under the bar (Zhang & He, 2012). Students' ability to use science (Physics, Biology, and Chemistry) in daily life is also still low (Wei, 2009). Good learning of science should be by connecting science content with the day-to-day experience. Laboratory experiments are one way for students to understand science content and relate it to daily life situations.

Problems related to integrated science are not only faced in schools, but also at the university level. The quality of lecturers is one crucial factor in the success of integrated science implementation; lecturers teach preservice science teachers that will educate integrated science in secondary schools. Based on observations, most lecturers of integrated science are not from science education but rather from Physics, Biology, or Chemistry Education. Also, lecturers did not conduct research focusing on themes related to integrated science. This fact is supported by a study done by Zhang & He (2012), which illustrates the inadequate quality of lecturers in teaching integrated science courses.

Lecturers' quality will have a direct impact on preservice science teachers' quality. Previous studies indicate that preservice science teachers also encounter several difficulties. Their mastery of integrated science's initial concepts is still considered insufficient. They tend to answer questions based on one discipline, not by linking it with other disciplines (Winarno, Widodo, Rusdiana, Rochintaniawati & Afifah, 2019). Presumably, this is due to integrated science being taught only at the secondary level and not at a senior high level. This finding is in line with the finding of research carried out by Zhang & He (2012). They found that college entrance tests in China do not incorporate integrated science subjects, and instead, they use three traditional subjects of Physics, Chemistry, and Biology separately (Zhang & He, 2012). Setiawan (2015) adds that problems relating to integrated science are not only encountered at the beginning of lectures, but also throughout the implementation of integrated science in the classrooms. These include the difficulties faced by preservice science teachers in implementing integrated science. A study was done by Parmin, Sajidan, Ashadi, Sutikno, and Fibriana (2017) reaped similar results; they found that preservice science teachers are yet to possess scientific work independence as they still rely on their lecturers when conducting experiments in class. There is a need for preservice science teachers to be able to develop integrated science learning instruments.

Zhang & He (2012) further elaborate the complications in the implementation of integrated science: (1) the inadequate quality of lecturers in integrated science teaching are considered low; (2) the existing curriculum has not yet reflected integrated science; (3) subject matters are not fully integrated; (4) most learning is done through lecturing; (5) topics taught on the nature of science are still insufficient; (6) teachers that do not come from the integrated science department; (7) teachers have not received preparation training on integrated science teaching. In addition to teachers, students, lecturers, and preservice science teachers, the government also plays an essential role in the success of integrated science. The government of several countries admitted that the implementation of integrated science is still met by problems, especially for teachers. That being said, the government should employ integrated science specialists (Otarigho & Oruese, 2013).

Problems in the implementation of integrated science also occurred in Indonesia. In 2013, there was a change in the curriculum: from the 2006 curriculum (SBC) to the 2013 curriculum. There is one major difference between the two curricula at secondary school level: in the 2006 curriculum (SBC), science subjects were taught separately hence providing no connection between Physics, Chemistry, and Biology. Meanwhile, in the 2013 curriculum, the three subjects are integrated hence showing connections between one subject and another. The curriculum change marked the beginning of integrated science implementation at the secondary level in Indonesia.

Nevertheless, most teachers do not possess the educational background of Science Education (integrated science major). Most of them come from Physics, Chemistry, or Biology Education department. A teacher with a Biology

Education background is obliged to teach Physics and Chemistry as well. However, at the university, they are taught General Physics (Fundamental of Physics) and General Biology (Fundamentals of Biology) exclusively in the first semester within an only 6-month duration. Throughout the second, until the last semester, they only focus on courses related to Biology and pedagogy. Also, based on the results of curriculum analysis, the curriculum in Physics, Biology, or Chemistry Education department does not incorporate integrated science. Therefore, prospective teachers are not equipped with adequate mastery and knowledge to teach integrated subjects.

The limited availability of integrated science textbooks is also a hindrance when teaching integrated science in the classroom. Currently, some topics in the existing textbooks have not been well integrated. This fact is in line with the results of a study showing that the availability, suitability, and use of integrated science teaching materials in schools still need to undergo major reworking (Zhou & Botha, 2008). Based on this fundamental alone, integrated science learning tools must be developed as an alternative solution to address this problem. There are several studies related to the development of integrated science learning devices: one study produced instruments on the topic of energy explained in three disciplines of Physics, Chemistry and Biology (Opitz, Neumann, Bernholt & Harms, 2017); another one developed integrated science learning devices with humanistic approach assisted by props (Widiyatmoko, 2013); one generated inquiry-based integrated science worksheets (Putri & Widiyatmoko, 2013); the last one developed integrated science learning media based on science-edutainment on the topic of conservation (Taufiq, Dewi & Widiyatmoko, 2014).

Based on observations and interviews of researchers at several schools and universities. We stated that when Indonesia implemented the 2013 curriculum, there were many obstacles at the beginning of its implementation. Fortunately, these issues have been addressed, resulting in better implementation of integrated curriculum compared to previous years. There have been developments in secondary school textbooks as well. Many universities have started to make available Science Education department. The department is organized to prepare science teachers for the secondary level. These preservice teachers are expected to be able to teach integrated science, hence taught not only Physics, Chemistry, or Biology but also integrated courses. They are prepared to not only teach science discipline, respectively but also showing connectedness of all disciplines in an integrated manner. Meanwhile, students from Physics, Chemistry, and Biology Education are prepared to teach at the high school level.

All in all, it can be concluded that the implementation of integrated science is still confronted by problems and in various countries to boot. According to all stakeholders involved, the implementation of integrated science did not prove out as successful as expected. Students find integrated science difficult, boring, uninteresting, and abstract. Other problems to mention are teachers not coming from the Science Education department, textbooks not being well integrated, developed curriculum not reflecting integrated science, and more to be addressed.

How is the effectiveness of integrated science learning?

Research on integrated science learning has been published in various countries. The research methods also used varied: descriptive methods, case studies, interviews, observations, surveys, quasi-experiments, qualitative methods, quantitative research, and questionnaires. Based on the results of the literature review, learning with an integrated science approach has positive impacts on secondary school, high school, and undergraduate students as well as teachers.

Several studies are using a quasi-experiment to investigate the effect of integrated science learning on secondary school students. The results show that learning integrated science using guided discovery models can increase scientific literacy with a gain score of 0.37 (medium category); meanwhile, problem-based learning can increase scientific literacy with a gain score of 0.41 (medium category). That said, integrated science learning using a guided discovery model and problem-based learning are proven to improve students' scientific literacy (Ardianto & Rubini, 2016). Several other studies also support these findings, stating that integrated science learning using problem-based models in the lesson study can improve scientific work skills as well as students' learning outcomes (Rahayu, Mulyani & Miswadi, 2012). Another study conducted by Alake and Ogunseemi (2013) shows that integrated science learning with scaffolding strategies improved students' academic achievement compared to traditional methods.

Integrated science learning also has a positive impact on high school students. One study conducted a used survey method. The results show that students benefited and experienced greatly after integrated science learning (Ebersole & Kelty-Stephen, 2017). Also, another research using the quasi-experiment method on 258 high school students was also carried out. The results prove that experiments in class on the topic of digestion, conducted with an interdisciplinary teaching approach, resulted in better conceptual understanding compared to the control class (Putica & Trivić, 2017).

Integrated science learning was also implemented at the university level for preservice science teachers. Some studies prove that Science Integrated Learning (SIL) is effective for the development of science content (Parmin, Nuangchalerm & El Islami, 2019) as well as improving scientific work independence of preservice science teachers (Parmin, Sajidan, Ashadi, Sutikno & Fibriana, 2017). Several other studies also support these results. The findings include: the implementation of learning using interdisciplinary curriculum can have a positive impact on preservice teachers' understanding as well as their knowledge of the nature of science (Uyar, Demirel & Doganay, 2018); it can also increase preservice teachers' understanding of integrated curriculum (Zhou & Kim, 2010); it also makes them able to connect natural science with other disciplines (Çinar, Pirasa, Uzun, & Erenler, 2016). Integrated science learning can also be implemented with other learning methods or approaches, such as simulation and laboratory methods. Van Hecke, Karukstis, Haskell, McFadden & Wettack (2002) explain that learning with the Interdisciplinary Laboratory approach received positive responses compared to traditional learning. Also, there is a cognitive and pedagogical improvement in integrated science courses with simulation methods (Setiawan, 2015). The findings from Agoro & Akinsola (2013) also show that the preservice science teachers' achievements and process science skills in integrated science can be improved with Reflective-Reciprocal Peer Teaching Strategies. Studies on integrated science learning were not only done on preservice science teachers but also 78 Physics students and 28 Elementary preservice teachers. The results show that classes with an integrated science curriculum produced a high level of satisfaction and confidence (Beichner et al. 1999); there is also an increase of interdisciplinary knowledge of Elementary preservice teachers (An, 2017).

Studies on integrated science learning have also been done on science teachers. The results indicate that during the implementation of integrated science, there are changes in several aspects of science teachers: updated science content knowledge reshaped conception of science teaching, increased collaboration with teachers, and built relationships with students (Wei, 2018). More research results also explain that integrated science teaching gives way for the development of new conceptual structures (Lang & Olson, 2000). Additionally, integrated science is also implemented by using learning media or learning devices. Learning outcomes of integrated science with learning media based on science-edutainment on the topic of conservation increased significantly (Taufiq, Dewi & Widiyatmoko, 2014). Putri and Widiyatmoko (2013) also elaborate that integrated science worksheets were effective for use in learning. On the challenges of the global community, integrated science learning must involve learning innovation. Therefore, integrated science teachers must know the right learning strategies and develop the ability to use different approaches creatively (Alake & Ogunseemi, 2013). One factor that influences the successful implementation of integrated science is input and output related to teacher quality. That includes mastery of teacher content, professional development experience, and an adequate planning period (Huntley, 1998). Training on integrated science for teachers is also necessary to improve teachers' competence. Rubini, Ardianto, Pursitasari & Hidayat (2018) prove that an integrated science training program can improve teachers' knowledge of scientific literacy, integrated science learning concepts as well as on designing integrated science learning.

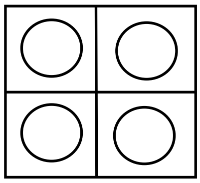
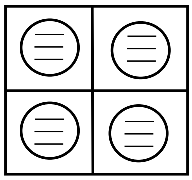
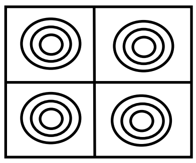
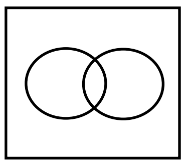
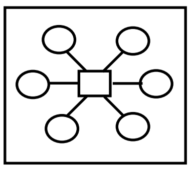
Despite the occurring problems in the implementation of integrated science, the research results are in line with the reasons and objectives of UNESCO to introduce integrated science to various countries. Those reasons include: (1) integrated science needs to be introduced as an element in basic education; (2) teaching integrated science at the secondary level is more appropriate when compared to teaching science per discipline; (3) teaching integrated science at primary and secondary levels can provide a strong foundation for students to learn more integrated science or specialist subjects; (4) everyone has the right to obtain basic or general knowledge because our daily life is always related to science, and learning integrated science can improve scientific literacy; (5) human environment is not separated into certain disciplines (Physics, Chemistry, or Biology), but it is always related to several subject areas. Thus every human being must learn science in an integrated manner to gain knowledge about their environment; (6) learning using integrated science offers students a general view of the world of science; (7) the development of modern science these days pertains to the interdisciplinary nature of science such as biochemistry, astrophysics, geophysics, etc.; (8) scientific process through an integrated approach can be one of the unifying factors for various science subjects (Physics, Chemistry, Biology or others); (9) science is considered as fragmentary (fragmented science) (Olarewaju, 1994; Oludipe, 2012). All things considered, learning with an integrated science approach is effective for the improvement of students' preservice science teachers' and science teachers' skills.

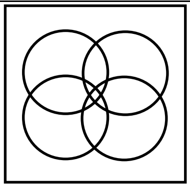
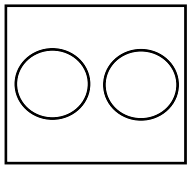
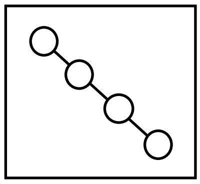
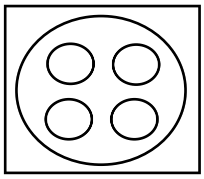
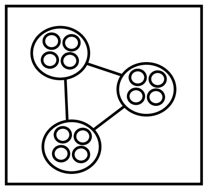
How to integrate science?

Integrated science is a science that integrates a variety of different disciplines such as Physics, Chemistry, Biology, Earth, Space Science, etc. One way to integrate science is by adapting an integrated curriculum (Elvionita & Fauzi, 2019; Rahmiwati, 2018; Rustam & Fauzi, 2019). Integrated curriculum is also called interdisciplinary teaching, synergistic teaching, or thematic teaching (Malik & Malik, 2011). According to Wall and Leckie (2017), an integrated curriculum is also called an interdisciplinary curriculum, multidisciplinary curriculum, content integration, and core curriculum. There are four aspects of integration: integration of knowledge, integration of experiences, social integration, and integration as a curriculum design (Beane, 1993). One approach to implement the curriculum at the middle level is curriculum integration (National Middle School Association, 2003). Some studies that mostly adapted integrated curriculum developed learning tools or teaching materials related to integrated science. This is due to the limited integrated science teaching materials that become one of the problems when implementing integrated science in the classroom (Sun, Wang, Xie, & Boon, 2014). The development of textbooks or integrated science modules is beneficial for students. Thang and Koh (2017) state that integrated science modules can increase students' confidence and improve their skills related to information analysis, time management, and the use of information communication technology.

In integrating curriculum, there are three dimensions to consider: within single disciplines, across several disciplines, and inside the mind of the learner. On the dimension of within single disciplines, there are three models: cellular, connected and nested. There are five models on the dimension of across several disciplines: shared, webbed, integrated, sequenced, and threaded. Inside the mind of the learner dimension, there are two models: immersed and networked. All in all, there are ten models of curriculum integration (Fogarty & Pete, 2009). These models can be seen in table 7.

Table 7.
Models of Curriculum Integration

No	Dimension	Model	Description	Design
		Cellular	The traditional model of separate and distinct disciplines, as depicted by student learning standards in each discipline area.	
1	Within single disciplines	Connected	Within each subject area, course content is connected topic to topic, concept to concept, one year's work to the next, and relates ideas explicitly.	
		Nested	With each subject area, the teacher targets multiple skills: a thinking skill, and a content-specific skill based on standards.	
2		Shared	Shared planning takes place in two disciplines in which overlapping concepts or ideas emerge as organizing elements	
	Across several disciplines	Webbed	Webbed curricula represent the thematic approach to integrating subject matter	

No	Dimension	Model	Description	Design
		Integrated	The integrated curricular model represents a cross-disciplinary approach similar to the shared model.	
2	Across several disciplines	Sequenced	Topic or units of study are rearranged and sequenced to coincide with one another. Similar ideas are taught in concert while remaining separate subjects.	
		Threaded	Standard, thinking skills, social skills, graphic organizers, technology, and a multiple intelligences approach to learning thread through all disciplines.	
		Immersed	The individual integrates all data, from every field and disciplines, by funneling the ideas through his or her area of interest.	
3	Inside the mind of the leaner	Networked	The networked model of integrated learning is an ongoing external source of input, forever providing new, extended, and extrapolated or refined ideas.	

Out of the ten models, one can be chosen for use to explain or develop an integrated science textbook. The selection of the integrated curriculum model must be adjusted to the characteristics of the topic or theme because each topic in the field of science has different characteristics. One example of a topic that can be explained using the shared model is a simple machine in the subtopic of the lever. Simple machines (lever) can be explained in two disciplines: Physics and Biology. The example of a shared model design on a simple machine (lever) can be seen in Figure 2.

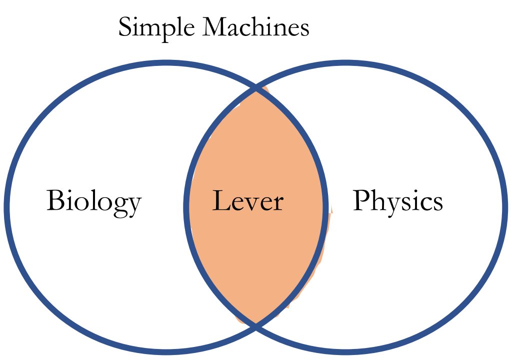


Figure 2.
Shared Model on the topic of Simple Machine (Lever)

Based on Figure 2, the explanation of simple machines in Physics is the mechanical advantage of a lever and the three classes of levers. Meanwhile, in Biology, levers exist in the topic of the human body (Hsu, 2003). The examples of simple machines in Physics can be seen in Figure 3, and Biology can be seen in Figure 4.

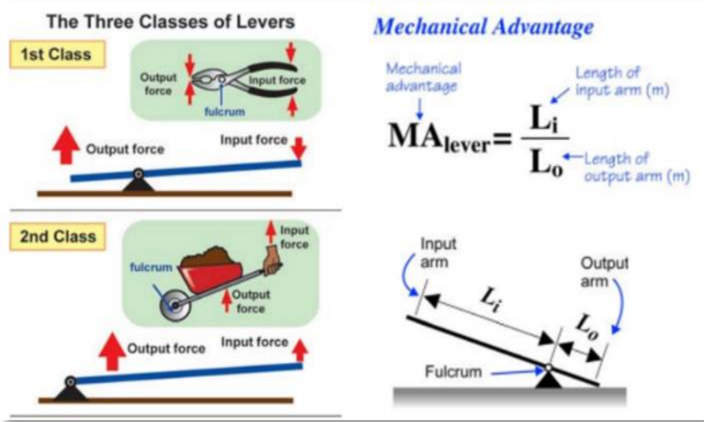


Figure 3.
Simple Machines (Lever) in Physics

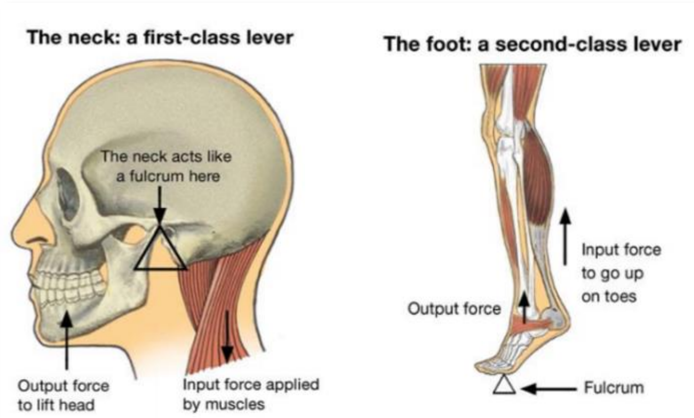


Figure 4.
Simple Machines (Lever) in Biology

In sum, it can be concluded that there are ten models of curriculum integration: (1) cellular, (2) connected, (3) nested, (4) shared, (5) webbed, (6) integrated, (7) sequenced, (8) threaded, (9) immersed, (10) networked. The development of integrated science textbooks can adapt several models as a basis for integrating selected topics.

What are the advantages and disadvantages of learning with integrated curriculum models?

In choosing the integrated curriculum model to implement in integrated science, the advantages and disadvantages of each model must be considered. Each topic in the field of science has different characteristics. Some topics can only be explained with certain models. The advantages and disadvantages of each model can be seen in Table 8.

Table 8.
Advantages and Disadvantages of Integrated Curriculum Models

No	Model	Advantages	Disadvantages
1.	Cellular	- Each discipline is not overlapped with others, so the purity of each discipline is left untainted. - Teachers are prepared to become an expert in a particular field. Thus they are to explore a certain discipline widely and deeply	- Students can become overwhelmed; - Students do not understand related overlapping concepts.
2.	Connected	- Students can understand the connectedness of concepts within one discipline.	- Connected models do not encourage teachers to collaborate, so the content remains the focus without

No	Model	Advantages	Disadvantages
		- Students can see the big picture as well as engage in a focused study of one aspect. - Students see an all-encompassing picture rather than a narrow one.	stretching concepts and ideas across other disciplines.
3.	Nested	- Students can combine various skills and concepts to achieve more complexity and depth in the lessons.	- Students carry out multiple learning tasks at once, so the conceptual priorities of the lesson may become obscure. - There is little actual transfer or application of skills and concepts.
4.	Shared	- Students can integrate two different disciplines; - Shared model is employed in the initial phase prior to using integrated models that combine four disciplines; - The shared model facilitates deep learning of overlapping concepts for transfer.	- It takes more planning time to develop the unit; - Profound dialogues are required in order to understand overlapping concepts; - It takes commitment between teachers (partnership) to collaborate through the initial phase.
5.	Webbed	- Selected themes are the result of motivating factors of high interest; - It eases students in understanding the connectedness of ideas within a theme; - It eases brainstorming of different activities, products, and projects that mirror the selected themes; - This model facilitates teamwork planning when teams across departments collaborate.	- There will be difficulties in selecting the theme; - There is a tendency to select shallow themes; - Teachers become more focused on activities rather than concept development.
6.	Integrated	- Students can understand connectedness and links between disciplines; - This model caters to across departments and can foster an appreciation of staff knowledge and expertise.	- This model is difficult to implement fully; - It requires high-skilled teachers and good knowledge of each discipline; - Each discipline takes a lot of commitment.
7.	Sequenced	- Teachers can determine curriculum priorities by rearranging the order of topics, chapters, and units; - Teachers can make critical decisions on contents; - The sequencing of related topics across disciplines can help students understand their studies in both subject and content areas.	- It requires discussion with a partner to shape the sequenced model; - Teachers partner with others, so they must give up autonomy in making curriculum sequences.
8.	Threaded	- Students can understand the contents of each discipline and possess the benefits to improve their life skills;	- Content connections across subject areas are not addressed explicitly.

No	Model	Advantages	Disadvantages
		- Teachers emphasize the metacognitive behavior so that students can learn about how they learn.	- There is the necessity of adding "another" curriculum, for example, thinking skills or social skills.
9.	Immersed	- Integration must take place within the learners; - Students can integrate all data, from every field and disciplines, by funneling the ideas through his or her area of intense interest - The connection making of this learner is often made explicit to other learners as the expert makes advances in the field.	- The filtering of all ideas through a single microscopic lens may occur too prematurely or with too narrow a focus.
10.	Networked	- This model is extremely proactive in nature, with learners initiating searches and following the newly emerging path; - Students are stimulated with relevant information, skills, or concepts that move their learning along.	- If taken to extremes, it can spread interests too thin and dilute a concentrated effort.

Research related to integrated science by adapting integrated curriculum models has been conducted. Such studies are developing because the implementation of integrated science still did not prove out as successfully as expected (Ogunkola & Samuel, 2011; Oludipe, 2012; Zhang & He, 2012; Sun, Wang, Xie, & Boon, 2014). Thus, scholars are keen to address these problems. One of the issues is integrated science textbooks. Several studies were stating that integrated science textbooks on the topic of sense of sight and optical devices have not been developed to the fullest (Weri, 2019). Also, integrated science books used in schools do not meet the required 21st century's topic of character education, critical thinking, problem-solving, and creative thinking (Hidayat, 2019). Thus, research that develops integrated science textbooks using the ten integrated curriculum models (cellular, connected, nested, shared, webbed, integrated, sequenced, threaded, immersed, and networked) can be employed as an alternative. So there will be more studies in science education with an integrated curriculum as a basis for integrating science disciplines such as Physics, Chemistry, Biology, etc.

The development of textbooks adopting integrated curriculum models can help improve students' skills. Several studies have stated that textbooks using webbed models can increase students' preparedness (Elvionita & Fauzi, 2019). Textbooks using shared models can improve students' competence (Rahmiwati, 2018), and textbooks with connected models can improve students' responsiveness and skills on the topic of sense of sight and optical devices (Rustam & Fauzi 2019). Also, Gusnedi, Ratnawulan, and Devialita (2019) further explain that experiments in the classroom abiding by textbooks with sequenced models improve students' learning outcomes compared to control class on the topic of the human body adaptation system. All findings considered, integrated science textbooks with integrated models are likely to generate a positive impact on students.

Currently, existing studies do not only employ the ten models as a basis for developing integrated science textbooks, but also an integrated curriculum model as an integrated science learning approach in the classroom. This statement is supported by the results of several studies proving that learning with an integrated model can improve science learning outcomes compared to the fragmented (cellular) model (Fazriyah, Supriyati, & Rahayu, 2017). This is due to several advantages; one of them is it enables students to understand the connectedness and interrelationships between various disciplines. This model understands across departments and can foster an appreciation of staff knowledge and expertise. However, the implementation of integrated models in learning also has some weaknesses. One of them is that this model is difficult to implement fully. It requires high-skilled teachers with good knowledge in their respective disciplines. Each of these disciplines also requires high commitment (Fogarty & Pete, 2009).

Despite the advantages, cellular models also have disadvantages in the implementation. The cellular model (within the single discipline) is the traditional model of separate and distinct disciplines, as depicted by student learning standards in each discipline. One advantage of using cellular models is that each discipline is not related to another, maintaining its organic nature. Teachers are prepared to become an expert in a particular field, hence enabling them to explore their respective discipline widely and profoundly. Besides, cellular models may overwhelm the students and make them fail to understand the related overlapping concepts (Fogarty & Pete, 2009; Wei, 2009).

Some researchers have attempted to compare the effectiveness of one integrated curriculum model with another. One study proves that shared models are more effective in increasing students' creativity compared to integrated models on the topic of waste recycling (Mariyam, Kaniawati & Sriyati, 2017). However, these results will not necessarily come to if applied to different topics due to the different characteristics of the topics (Venville, Wallace, Rennie, & Malone, 2002). In summary, it can be concluded that the integrated curriculum can be used as a basis for developing integrated science textbooks. The integrated curriculum can also be used as an approach to learning integrated science. Each integrated curriculum model has its strengths and weaknesses.

The results of this study show that integrated science has been implemented in various countries. Nonetheless, the implementation of integrated science did not prove out as successful as expected. Students find this method of learning difficult, boring, uninteresting, and abstract. There are several issues in the implementation of integrated science learning: the inconsistency of teachers' educational backgrounds with integrated science, as well as underdeveloped textbooks and curriculum.

Conclusion

There are several problems related to the implementation of integrated science. One of the problems is the limited information and sources of reference for integrated science. Science education researchers have difficulty finding reputable journals because the number of publications relating to integrated science is very limited. Based on interviews with teachers or lecturers on science education in Indonesia, they lack an understanding of integrated science in depth. So, this study is very important because it will provide information related to integrated science comprehensively to researchers, lecturers, preservice science teachers, science teachers, or other stakeholders. Also, the current trend of modern learning leads to interdisciplinary (integrated) learning that connects one discipline with another. In this study, we explain the definition of integrated science, the history of the implementation of integrated science, countries that have implemented integrated science to date, the investigation of the implementation of integrated science, the effectiveness of integrated science learning, the integration of science, and the advantages and disadvantages of integrated curriculum models.

Integrated science is a science that integrates a variety of different disciplines (Biology, Chemistry, Physics, Microbiology, Ecology, Earth Science, and Astronomy). In 1967, the first international symposium on integrated science education was held in Lausanne, Switzerland. Since the international conference, there have been several follow-up seminars held to introduce integrated science. The results of this study show that integrated science has been implemented in various countries. Nonetheless, the implementation of integrated science did not prove out as successful as expected. Students find this method of learning difficult, boring, uninteresting, and abstract. There are several issues in the implementation of integrated science learning: the inconsistency of teachers' educational backgrounds with integrated science, as well as underdeveloped textbooks and curriculum. Learning with an integrated science approach is effective for improving some student skills. Ten models can be employed in integrating science: cellular, connected, nested, shared, webbed, integrated, sequenced, threaded, immersed, and networked. The development of integrated science textbooks can adapt several models as a basis for integrating selected topics or themes. Also, models from the integrated curriculum can be used in science learning. The implementation of an integrated curriculum must consider the compatibility between the model and the topic. The compatibility needs to be considered for each integrated curriculum model has strengths and weaknesses, and each topic in science also has different characteristics.

Recommendations

Based on the explanation above, researchers provide several suggestions to address problems related to integrated science. Lecturers who teach integrated science courses should have expertise in integrated science. Also, the lecturers' research must focus on integrated science. The quality of the lecturers will have a positive impact on preservice science teachers. If preservice science teachers are of high quality, it will have a positive impact on their students. Teachers of integrated science must come from the science education department. Those who are not are expected to attend training, workshops, seminars related to integrated science. There must be shared knowledge between teachers of different backgrounds. Textbooks at the secondary level, especially in Indonesia, need to be continuously supervised and revised to improve the quality. Presently, the availability of integrated science textbooks at the university level is still limited. Therefore, stakeholders in science education are expected to develop integrated textbooks adaptive to the curriculum in use. At the university level, courses on integrated science must be introduced in the first years. After full comprehension of concepts, courses on integrated science learning (Pedagogy Content Knowledge) can be offered. These courses provide the know-how to develop integrated science textbooks and ways to teach integrated science (microteaching).

It is recommended for future research to investigate problems of integrated science by analyzing a sample of research, for instance, integrated science lecturers at the university level. This is due to the unavailability of studies from international journals that analyze lecturers. Besides, the literature of international journals on integrated science is very limited. Therefore, the results of this study are useful to use as an additional reference for teachers, lecturers, researchers, or other stakeholders of integrated science.

Limitations of the Study

All articles analyzed are related to integrated science. Integrated science in this study is to integrate several disciplines such as Physics, Chemistry, or Biology. The articles were published from 1996 to 2019.

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