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Research trends on biology digital modules: A bibliometric analysis

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ABSTRACT

Currently there is widespread interest in the use of digital modules for learning. The availability of studies on research trends and development of digital modules, can be a need analysis for further development of digital modules. Therefore, this bibliometric analysis was conducted to explore research trends on biology digital modules over the last decade. The data used in this study are Google Scholar indexed articles in 2012-2022. A search through the Publish or Perish (PoP) application using the keywords "modul digital" OR "digital module" OR "e-modul" from 2012-2022 obtained 988 results, then the remaining 41 articles were analyzed using Microsoft Excel to analyze the data descriptively and VOSviewer to obtain bibliometric mapping visualizations. Based on a bibliometric analysis study in the area of biology digital modules , it is known that publications about biology digital modules have been recognized since 2015 to 2022, reaching a peak in 2021, and most of them come from Indonesia. The most widely applied type of research is R&D involving high school students. Critical thinking skills are one of the 21st century skills that are most widely included in biology digital modules . Network visualization shows that there are 45 terms that are relevant to the digital biology module and are grouped into 3 clusters. The overlay visualization shows that "STEM" is a term that will appear in the 2022s. Density visualization shows that "e-module", "research", and "development" are the 3 terms with the highest density. The findings of this study are expected to be a reference for other researchers in optimizing the role of digital modules to support student learning.

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INTRODUCTION

Education systems around the world are challenged to become more inclusive, improve the quality of learning provision and be more responsive to societal and economic needs. These challenges are clearly expressed in the framework of the fourth Sustainable Development Goals (SDG) action, namely "Ensure inclusive and quality education for all and promote lifelong learning" (Demirbağ & Sezgin, 2021; UNDP, 2015). To support this mission, one of the efforts is to provide learning resources that can be accessed easily and free of charge. Teaching materials or educational materials that are freely available and openly licensed so that they can be accessed, reused, and widely distributed by educators, students, and the general public are known as Open Educational Resources (OER) (Davis et al., 2016). The development of OER as an information and communication technology (ICT)-based learning resource has been carried out by many institutions, practitioners, teachers in the field of education. Especially with the COVID-19 pandemic which has succeeded in transforming education to become very closely related to ICT, especially the use of digital modules to facilitate online or distance learning.

In the context of learning, the module is a unified package or learning program, starting from planning, implementation, to evaluation which is prepared for an independent learning process (Gemuruh et al., 2022; Rizki et al., 2022; Shohibi et al., 2020). In learning, modules can act as supplements, complements, and substitutes for learning resources (Arianti et al., 2022; Hakim et al., 2021; Kumar et al., 2019). Digital modules are packaged into units of various types of media (text, graphics, audio, video) sequentially or simultaneously to present information (Kumar et al., 2019). Digital modules have many advantages compared to textbooks or printed versions of modules, because they are more interactive because they can navigate according to the needs and learning speed of each student, can get automatic feedback immediately when taking tests or quizzes, can be accessed using various student devices such as computers, laptops, tablets, or mobile phones (Furqan et al., 2015; Hidayatun et al., 2015; Noroozi§ & Mulder, 2017; Sari et al., 2021).

Currently there is widespread interest in optimizing digital modules for learning in schools and universities. Therefore, it is necessary to have an initial study that reports trends in research and development of digital modules, especially in the area of biology so that it can become an analysis of needs and potential in efforts to develop further digital modules. One approach that can be used to analyze trends in a research area is bibliometric analysis. Bibliometric analysis is a statistical analysis tool used in understanding global research trends and provides interesting quantitative information in the academic literature (Nicolaisen, 2010; Zhang et al., 2022). This type of approach distinguishes how a bibliometric analysis differs from a review paper which primarily wants to focus on recent advances, challenges, and future directions of the topics covered (Dewi et al., 2021; Zhang et al., 2022).

Researchers and educational practitioners are trying to develop various digital modules that function as supplements, complements, or substitutes for teaching materials, especially in biology learning in schools and tertiary institutions. However, at present, there have been very few attempts to systematically review the scientific publication of biology digital modules by using the bibliometric analysis. Therefore, to discuss this subject, we seek to review the development of biology digital modules from 2012 to 2022, in particular to identify the technicalities of producing biology digital modules, the use of biology digital modules in the classroom, and what skills are included in biology digital modules, keywords related to biology digital modules that are most often used, and important research themes in the field of biology digital modules. The results of this study are expected to be a means of benchmarking on best practices for the development and implementation of digital modules in biology learning, both hybrid and full online.

METHODS

Bibliometric analysis approach is used in this descriptive study. Bibliometrics is a statistical method used to handle scientific data, uncover research topics, reveal the development of science, and identify the impact of research. Furthermore, bibliometric analysis can assist in parsing and presenting more detailed, comprehensive, and accessible data. Through this method, the contribution of academic outcomes to the advancement of knowledge in specific subjects can be analyzed objectively and quantitatively (Wang & He, 2022; Yang et al., 2013). With this benefit, bibliometric analysis can help predict patterns and directions of development of a particular discipline (Dewi et al., 2021; Wang & He, 2022).

Data Sources and Search Strategy

There are three main stages carried out to obtain data for bibliometric analysis which refers to Zhang et al. (2022) namely identification, eligibility, and included. At the identification stage, the Publish or Perish (PoP) application was used to browse the literature on digital modules. The database used in this stage was Google Scholar indexed articles in the last 10 years, that is 2012-2022. Google Scholar was chosen because it can filter searches for full-text journal articles, including national journals indexed by Science and Technology Index (Sinta), which cannot be done by other indexing engines, such as Scopus and Web of Science.

By using PoP, search results with the keywords "modul digital" OR "digital module" OR "e-modul" from 2012-2022, 988 results were obtained. Search results were converted in RIS format. Due to the RIS file contains search results with Google Scholar which displays many sources, both articles, books and other documents, including selected web pages, it is necessary to filter the search results according to the criteria desired by the researcher. At the eligibility stage, the inclusion and exclusion criteria set to exclude irrelevant records are presented in Table 1.

Table 1
Inclusion and Exclusion Criteria.

Inclusion Criteria	Exclusion Criteria
• Studies are pertinent to biology digital modules.	• Studies do not address biology digital modules.
• Types of publications are published articles and conference papers which are nationally accredited and internationally indexed.	• Book, review paper, articles in press, web page, unpublish paper from university repository.
• The time span is from 2012-2022.	• The time span is earlier than 2012 and later than 2022.
• The full version of the publication is available.	• The full version of the publication is unavailable.

Based on the eligibility screening results, 41 articles were obtained which were then reviewed for completeness of metadata which included title, author(s), year, type of publication, volume, issue, DOI, abstract, and full-text paper.

The summary of data search carried out in this study was presented in Figure 1.

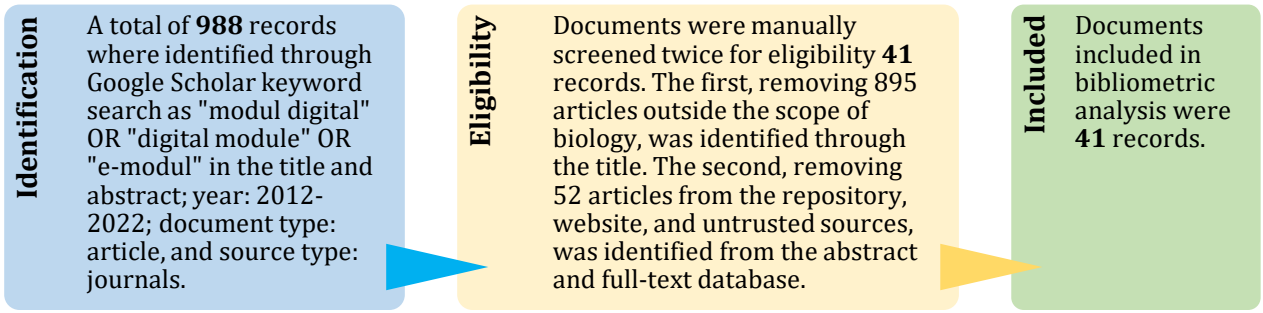

Figure 1. The Main Stages in Data Search in Bibliometric Analysis

Data Analysis

Once complete, the metadata of 41 articles were converted to CSV using Zotero. Then, CSV file was opened with Microsoft Excel to create a graphical presentation of descriptive data which includes distribution of research year by year, types of publications, types of research, modes, educational levels, biological topics, and dependent variables. In addition, the updated RIS file was used to create bibliometric mappings using VOSviewer. Before starting the visualization processing, the following arrangements were made: (1) choose fields based on title and abstract fields; (2) choose counting method by binary counting; (3) the minimum number of occurrences of a term was 3; (4) number of terms was 45; and (5) option panels setting are default (scale of visualization: 1,00; labels in circles; size variation of labels: 0,50; maximum length of labels: 30; size variation of lines: 0,50; minimum and maximum strength of line: 0 and 1000).

RESULTS AND DISCUSSION

A total of 41 articles on biology digital modules were published from 2012-2022 (Figure 2). Almost all publications (97.6%) come from Indonesia, while the rest are from the Netherlands. The

increasing trend of publications about biology digital modules occurred in 2020-2021, which is the time of the COVID-19 pandemic. At that time, learning and research were quite hampered because they could not interact directly with students in class. Therefore, research related to the development or implementation of learning innovation products in the form of digital modules is an alternative solution to this problem.

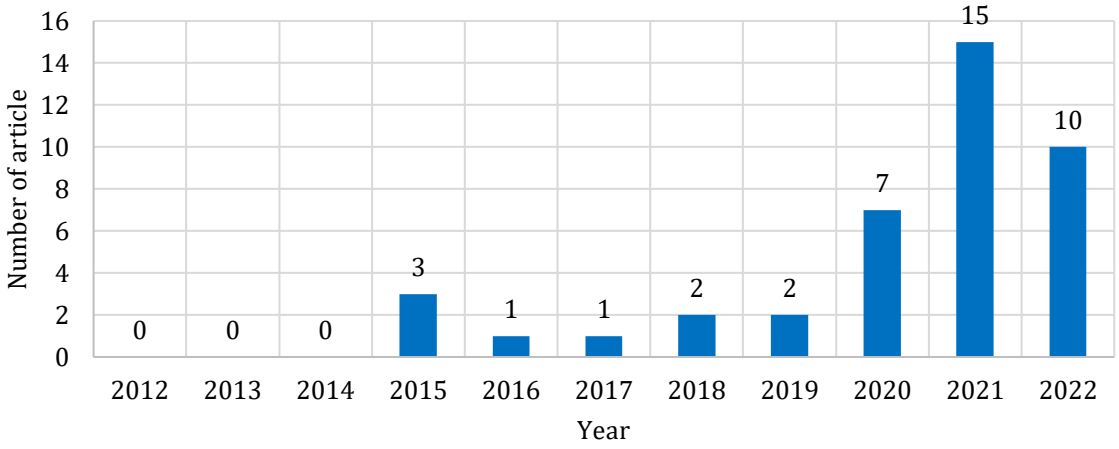

Figure 2. Distribution of Publication on Biology Digital Modules from 2012-2022

Publication of biology digital modules is carried out in journals and seminar proceedings, both nationally accredited and internationally indexed (Figure 3). The most publication of articles on biology digital modules is done in national journals, followed by international proceedings. Meanwhile, publications in international journals and national seminars are limited.

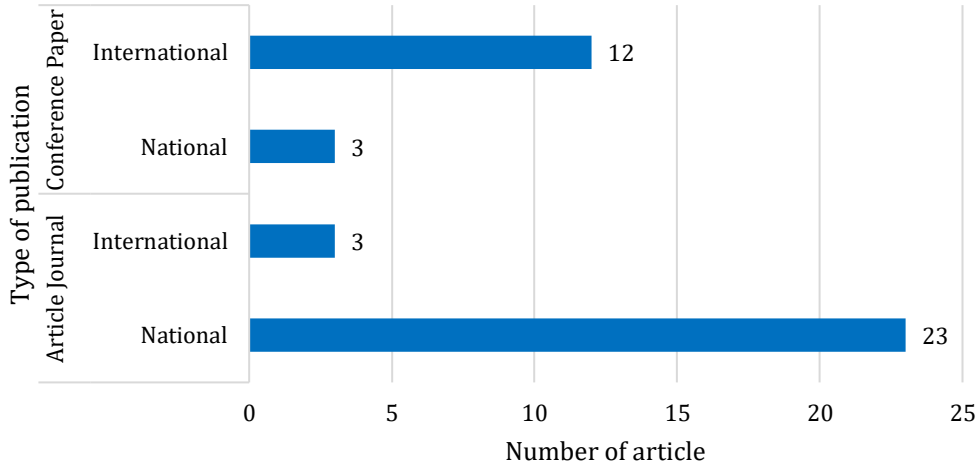

Figure 3. Proportion of Types of Publications about Biology Digital Modules

Publications about biology digital modules are the result of studies using different methods, including research and development (R&D), descriptive research, quasi-experiments, classroom action research, and pre-experiments (Figure 4). The most commonly used type of research is R&D. There are several R&D models used, including Analyze, Design, Develop, Implementation, and Evaluation (ADDIE) as carried out by Al-Muhdhar et al. (2021), Aprilia & Suryadarma (2020a), Aprilia & Suryadarma (2020b), Dalaila et al. (2022), Fidiastuti et al. (2021), Hakim et al. (2021), Hasibuan et al. (2020), Khasanah & Nurmawati (2021), Maulana et al. (2020), Nurrijal (2022), Puspridayanti et al. (2018), Putri et al. (2022), Rizki et al. (2022), Sari et al. (2020), dan Sari & Manuaba (2021); Borg and Gall model done by Nurjayadi et al. (2021), Ravista et al. (2021), dan Watoni et al. (2022); the Define, Design, Develop, Disseminate (4D) Thiagarajan model carried out by Arianti et al. (2022), Hidayati et al. (2019), Pamungkas & Oktasari (2020), dan Puluhulawa et al. (2022); the Dick and Carey model done by Shohibi

et al. (2020); the Rowntree model was carried out Vidianti & Qonita (2022). In addition, a small number of researchers did not mention the R&D model used, but mentioned the stages which included identification of potential and problems, design, validation, revision I, small-scale trial, revision II, large-scale trials, final revision (Afifah et al., 2018; Leonora et al., 2021).

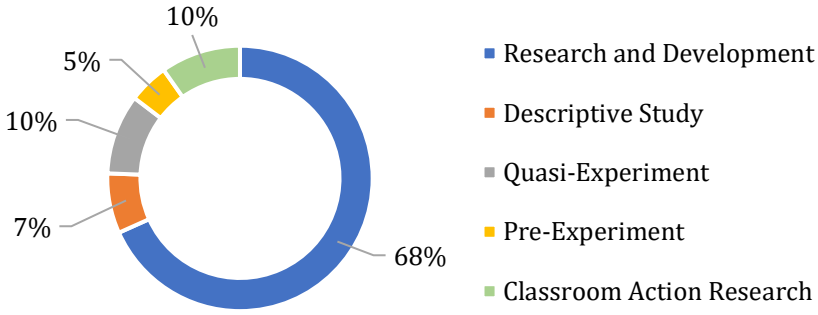

Figure 4. The Proportion of Types of Research on Biology Digital Modules

Digital modules are designed and developed using various applications, both free and subscription-based. Some of the commonly used applications include: Ncesoft flip book Maker, Kvisoft FlipBook Maker, Flip PDF Professional, iSpring Suite integrated with PowerPoint, Articulate Storyline, 3D Pageflip Professional, Sigil, and Canva. The digital modules developed can be operated online or offline using various devices, such as personal computers/laptops or mobile phones. Based on the results of the analysis, it is known that most (about 80%) of the digital modules developed can be accessed offline (Figure 5). The digital module is degenerated into a file in html or exe format so that it can be accessed via a PC/laptop and in apk format to be accessed via a mobile phone.

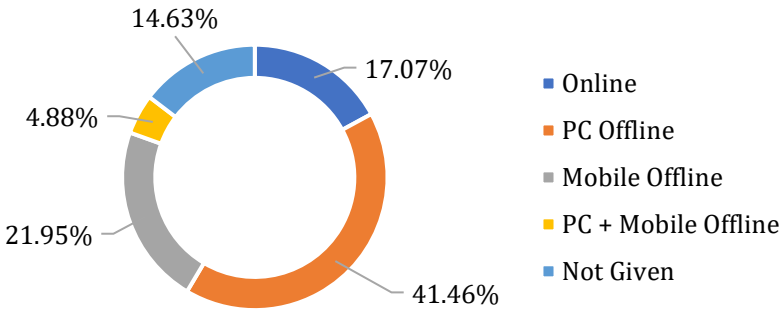

Figure 5. The Proportion of Modes of Digital Biology Module

The digital biology module was developed to facilitate learning at various levels of education (Figure 6). Based on the data, most digital modules are developed for biology learning at the senior high school level. At the tertiary level, biology digital modules have been developed by researchers quite a lot. Meanwhile, for the junior high school and elementary levels, digital modules have not been developed much.

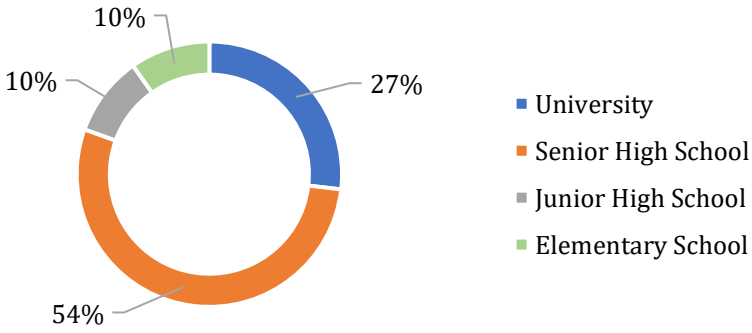

Figure 6. The Proportion of Educational Levels Enrolled as Trials for Biology Digital Modules

Digital modules are generally used as teaching materials for students in face-to-face (offline) and distance (online) learning. Biology digital modules are implemented in biology learning by using certain learning models, such as problem-based learning (PBL) (Diana et al., 2015; Furqan et al., 2015; Hidayatun et al., 2015; Imaningtyas et al., 2016) and integrated into the learning management system (LMS) (Hidayati et al., 2019; Maulana et al., 2020; Noroozi§ & Mulder, 2017; Nurrijal, 2022; Sari et al., 2020).

The following is a list of materials used as context in the development of digital modules (Table 2). Based on the data, there are 25 biological topics contained in the digital module. Ecology is the material most often made into digital modules, followed by material on the digestive system, immune system, and respiratory system.

At the university level, digital modules have been developed for several essential materials in biology, such as Genetics (Fidiastuti et al., 2021), Cell Biology (Hidayati et al., 2019), Introduction Molecular Life Sciences and Biotechnology (Noroozi§ & Mulder, 2017), Protein Structure and Function (Nurjayadi et al., 2021), Microbiology (Nurrijal, 2022), Plant Biosystematics (Pamungkas & Oktasari, 2020), Human Anatomy and Physiology (Rahmatika et al., 2021), Endocrine System (Rahmawati et al., 2021), dan Respiratory System (Sari et al., 2020, 2021).

Table 2
Percentage of Topics in Biology Digital Modules.

No.	Topic	Percentage (%)
1	Ecology	16
2	Human Digestive System	7
3	Human Immune System	7
4	Human Respiratory System	7
5	Biotechnology	5
6	Energy in Living Organisms	5
7	Environmental Changes	5
8	Genetics	5
9	Human Circulatory System	5
10	Human Nervous and Coordination System	5
11	Kingdom Plantae	5
12	Biodiversity	2
13	Cell Biology	2
14	Classification of Living Things	2
15	Enzyme	2
16	Human Anatomy and Physiology	2
17	Human Endocrine System	2
18	Human Excretory System	2
19	Human Reproductive System	2
20	Microbiology	2
21	Molecular Biology	2
22	Plant and Its Function	2
23	Plant Biosystematics	2
24	Plant Cell and Tissue	2
25	Protein Structure and Function	2

The digital biology module developed by the researchers aims to facilitate mastery of material on certain biological concepts, overcome misconceptions, increase learning motivation, intervene in student attitudes, provide literacy and certain skills (Figure 7). Based on data, critical thinking skills, scientific literacy, and creative thinking skills, respectively, are three aspects that are mostly included in biology digital modules.

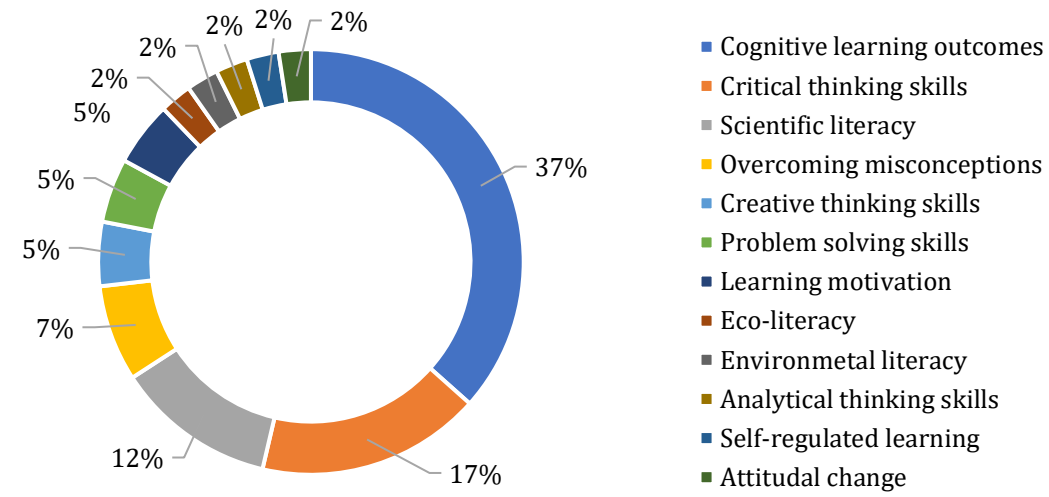

Figure 7. The Proportion of The Dependent Variable Inserted in Biology Digital Modules

Metadata extracted using VOSviewer with a minimum number of occurrences of a term were 3 obtained 45 items, 595 links, 3 clusters, and 1857 total link strength. The resulting visualization output is in the form of a bibliometric map consisting of network visualization (Figure 8), overlay visualization (Figure 9), density visualization (Figure 10). Network visualization illustrates the interrelationships between research themes.

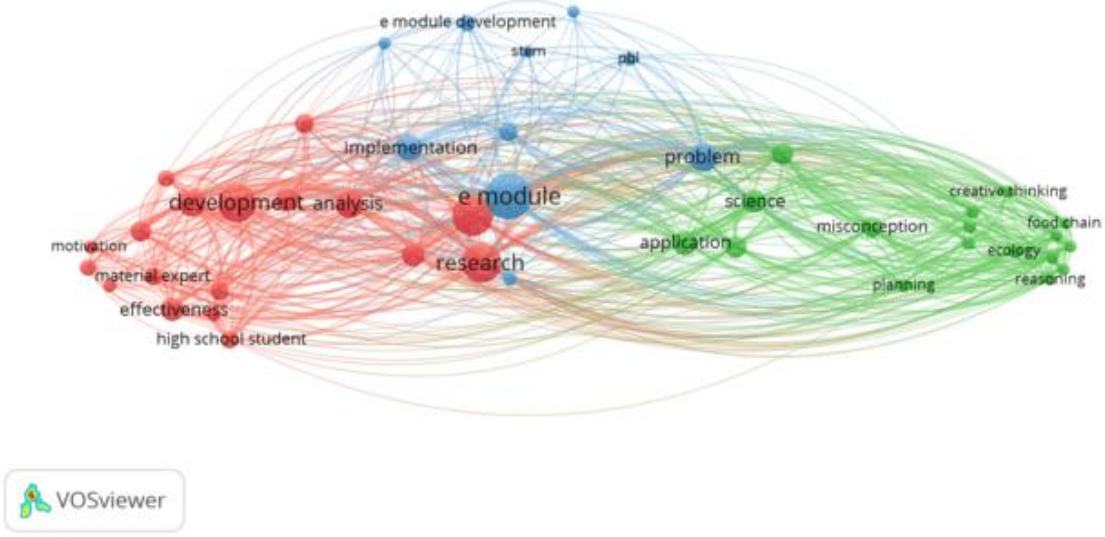

Figure 8. Network Visualization on Biology Digital Modules

Based on Figure 8, it is known that there are 45 items or terms that are relevant to the digital module which are clustered into 3 which are indicated by different color groups, namely red, blue, and green. The bigger the circle or the size of the text, the more often the item is discussed in a publication. In addition, the connecting lines between items show the interrelationships between items in a publication. The terminology covered in the three clusters is presented in Table 3.

Table 3
Bibliometric Map based on Cluster Color.

Clusters	Number of Item	Items
Red	18	ADDIE model, analysis, development, digital module, effectiveness, evaluation, high school student, learning, material expert, media expert, module, motivation, program, R&D, research, student, teaching material, validity
Blue	17	application, classroom action research, creative thinking, data

Clusters	Number of Item	Items
Green	10	presentation, data reduction, data validation, ecology, ecology concept, environment, food chain, misconception, planning, reasoning, salingtemas, science, technology, web activity, cognitive learning outcome, e module, e module development, implementation, online learning, PBL, problem, scientific literacy, STEM

Based on Table 3, the terminology related to digital modules is quite diverse, including those related to R&D models, digital module development stages, biology topics or materials, other variables contained in digital modules. The red cluster contains technical related keywords in producing and developing digital modules. One of the most used models is ADDIE. The ADDIE Model, which is an acronym for Analyze, Design, Develop, Implement, and Evaluate. ADDIE can serve as a guide framework for developing educational products and other learning resources (Branch, 2009). The blue cluster contains several terms related to the concept of ecology. One of the advantages of using the concept of ecology as content in biology digital modules is the availability of objects and phenomena in nature that are concrete in nature so that they can be observed and documented as content in digital modules, both as images and videos. In addition, digital module developers can also adjust to the characteristics of the ecosystem in their respective regions. Whereas in the green cluster, the keywords are related to the "soul" of a digital module. Apart from biology content, most of the research results report strategies for integrating 21st century skills in digital modules. For example, to train the ability to solve problems or scientific literacy about the environment, digital module developers conceptualize the flow and systematics of digital modules according to the problem-based learning (PBL) syntax or the Science, Technology, Engineering, and Mathematics (STEM) learning framework.

The overlay visualization shows the distribution of publications about digital modules by year of publication. Based on Figure 9, it can be seen that the purple circles are the terms “ecology”, “reasoning”, “creative thinking”, “misconceptions” published in the 2016s. Meanwhile, more recent publications are marked with a yellow circle, as in the term “STEM”. This indicates that there are opportunities for further research and development regarding digital modules with a STEM approach.

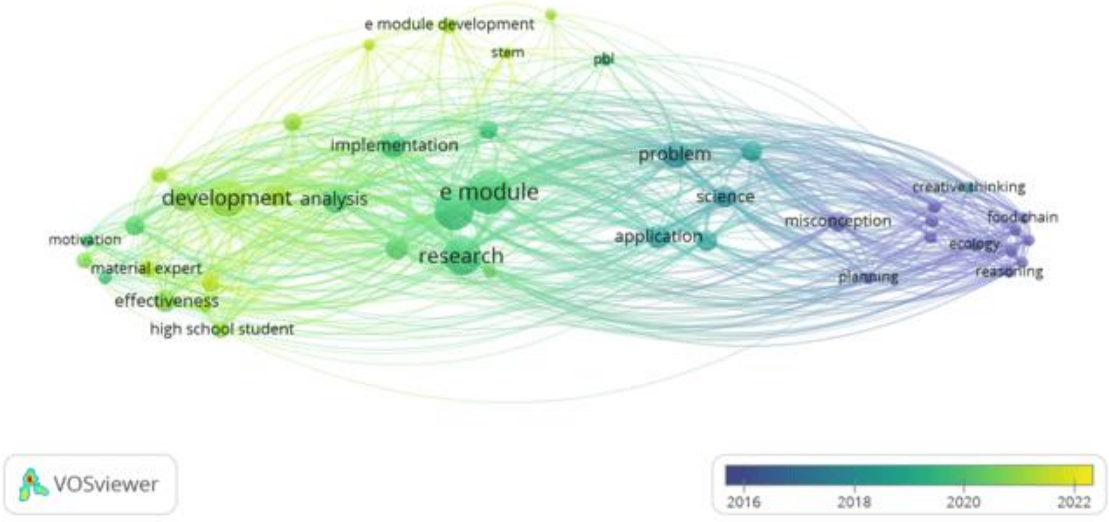

Figure 9. Overlay Visualization on Biology Digital Modules

Meanwhile, the density visualization shows the density of publication frequency over a certain period of time. The lighter the color of the yellow area, the denser the density of the item. Based on Figure 10 it is known that there are 3 items with the highest density, namely “e-module”, “research”, and “development”.

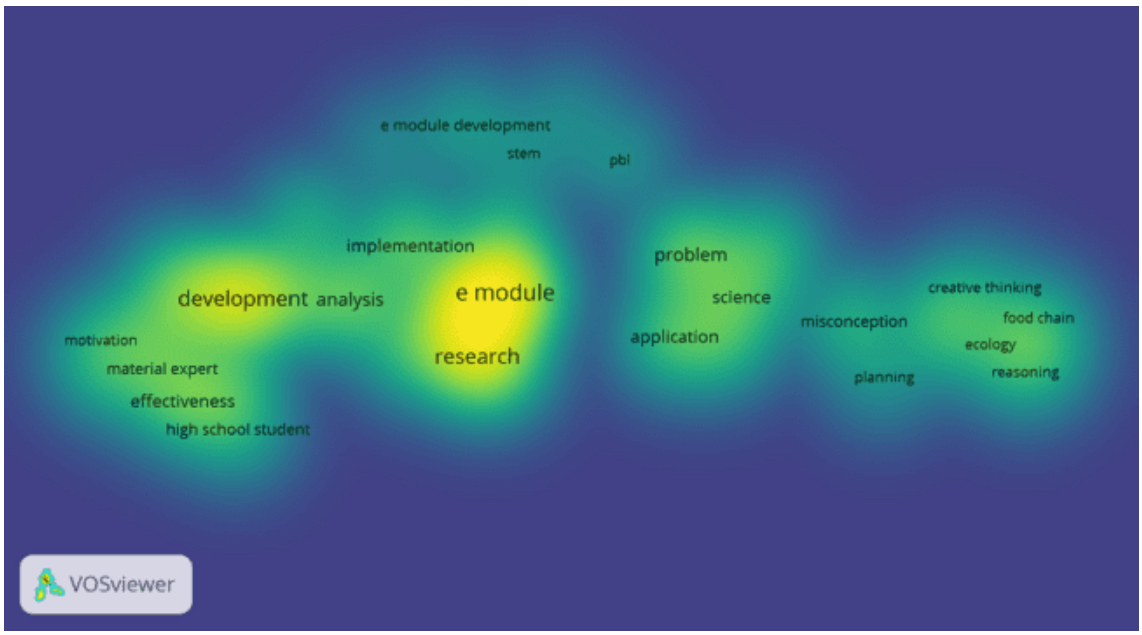

Figure 10. Density Visualization on Biology Digital Modules

Based on the findings obtained from this study, most biology digital modules were reported by authors from Indonesia. This is due to several supporting factors, including: (1) resources: the availability of various applications or programs that can be used to practically generate digital module files, both free of charge and requiring a subscription fee or purchase of a license; (2) digital literacy: the availability of various learning resources and sufficient references for developers to develop their digital modules, for example through video tutorials and free and paid learning; (3) pedagogical and content knowledge: the ability to package and present multimedia (text, images, animation, audio, and video) according to curricular objectives, so that it can be used to facilitate learning outcomes for students.

The digital biology module developed by the researchers not only facilitates students' mastery of biology concepts, but also incorporates 21st century skills, such as critical thinking skills, scientific literacy, and creative problem solving. Indirectly, the application of digital modules is able to train and familiarize students in utilizing digital learning resources. Several aspects that have the opportunity to be explored by future researchers include linking the effectiveness of digital modules to support learning in terms of learning strategies, learning styles (visual, auditory, and kinesthetic), as well as students' cognitive psychological potential.

Based on this study, most biology digital modules for school students are still limited to one separate concept or material. Meanwhile, digital modules developed in tertiary institutions are designed for serial learning in several meetings in one semester, for example the cell biology lecture series (Hidayati et al., 2019), biotechnology and molecular life sciences (Noroozi§ & Mulder, 2017), microbiology (Nurrijal, 2022). Based on this description, there are still opportunities to develop biology digital modules in tertiary institutions that are integrated with the LMS. In addition, if digital modules are available in foreign languages (for example: English), then they have the opportunity to be offered in open learning programs and have a wide reach of users.

CONCLUSION

Based on the results of this study, it is known that the trend of biology digital modules for the past 10 years will peak in 2021, which coincides with the COVID-19 pandemic. The use of digital modules in learning is a form of adaptation for educational practitioners and researchers in dealing with the impact of the COVID-19 pandemic by optimizing the role of ICT in learning. The digital module was chosen because it has several advantages over textbooks. From the pedagogical aspect, the module was chosen because it can be integrated with multimedia to represent concepts and packaged interactively in providing feedback, so that it can help students learn independently. Most of the research focuses on producing digital modules for certain materials and a small part integrates them with LMS. The developed module contains the skills needed for the 21st Century.

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