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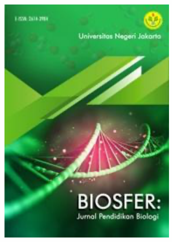

Empowering prospective teachers' scientific and digital literacy through exploring-resuming integrated criticizing (ERIC) in biology classroom

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ABSTRACT

Prospective Science teachers need well-developed science and digital literacy to help the process of thinking, learning, communicating, working together, and working with their creativity. Unfortunately, various studies show that students' abilities regarding these two types of literacy still need to improve, especially in first-year students. This study aims to (1) analyze the potential impact of the ERIC learning model with the lesson study-based TPACK framework on science and digital literacy and (2) analyze the contribution of lesson study implementation during ERIC learning to the professional development of educators. This study used a concurrent mixed method. In-depth analysis through lesson study was conducted during the implementation of the ERIC learning model in a quasi-experimental setting. The collected data was then analyzed using the ANCOVA test to reveal the difference in mean scores between the experimental and control classes. At the same time, the results of learning observations and reflection on the lesson study phase were analyzed qualitatively. The results showed that the ERIC learning model with the TPACK framework had a significant effect on scientific and digital literacy. In addition, implementing lesson study enables educators to become more aware of students' learning difficulties and needs and, therefore, develop deeper knowledge about learning requirements.

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INTRODUCTION

The Industrial Revolution 4.0 has transformed industrial and technological activities that have never been imagined (Prause & Atari, 2017; Oztemel & Gursev, 2020). This is what ultimately creates a gap between competition and changes in science and technology and the competencies possessed by the younger generation. Scientific literacy and digital literacy are two essential components of 21st-century science education, which aims to prepare future generations to think and be responsible for the impact of world progress, which is greatly influenced by developments in science and technology (Vieira & Tenreiro-Vieira, 2016; Luu & Freeman, 2011).

Scientific literacy is categorized by Gormally et al. (2012) into two skills, namely: (1) the ability to understand inquiry methods to obtain scientific knowledge and (2) the ability to organize, analyze, and interpret quantitative data and scientific information. This ability is needed to overcome problems and make the right decisions in various aspects of life (Cassidy et al., 2019). Another critical aspect of digital literacy essential to 21st-century education is mastery of digital literacy. Many educators believe digital literacy to be the core of literacy and is no longer seen as a complementary material for planning and implementing learning (Cassidy et al., 2016). This ability leads to an individual's ability to use technology appropriately to access, manage, integrate, analyze, and synthesize new information in solving problems and applying digital literacy in everyday life responsibly (Kaeophanuek et al., 2018). The development of students' literacy level and their digital competence is crucial for improving the effectiveness and efficiency of the learning process as well as for the adaptation of students to the dynamically changing labor market (Shopova, 2014; Khan et al., 2022).

Students in higher education level are expected to have a high level of science and digital literacy because these abilities are needed to help the process of thinking, learning, communicating, working together, and working with their creativity as preparation for entering the world of work. Unfortunately, various studies show that students' abilities regarding these two types of literacy still need to improve. For instance, in their research Coldwell-Neilson (2018) reported that academics expectations in Australian higher education institutions are far higher than what they observe of students' digital literacy capabilities and that digital literacy skills are not being adequately scaffolded and extended through the curriculum. In Indonesia, the results of a study on the digital literacy of students at one university showed that information literacy competency only reached 45.1% (Wardhani et al., 2019), while the overall level of student scientific literacy is still in the sufficient category (Adi et al., 2020). This condition aligns with the observations on Biology and Science education students, especially at the first year of study. It is also confirmed by a study conducted by Sukmawati et al. (2018) that the information literacy of Biology Education students at Universitas Tidar still needs to improve, especially regarding the use of information effectively and ethically.

Based on this description, the urgency of the problem in this research lies in the low level of science and digital literacy of prospective teachers. At the same time, these two types of skills are needed to help the learning process so prospective teachers can teach these skills to their students. Educators in higher education need to ensure that future prospective teachers need to develop scientific and digital literacy by supporting new and diverse learning methods that place students at the center of learning.

Various instructional designs and approaches have been identified as effective in enhancing scientific literacy among students and teachers. These include discussion methods, personal science writing, argumentation on environmental issues, inquiry-based learning, differentiated instruction (Nugraeni & Paidi, 2021), and computer-based interactive simulations (Fan & Geelan, 2013). Furthermore, some learning model such as guided discovery and problem based learning (PBL) can be used to build students' scientific literacy (Ardianto & Rubini, 2016). On the other hand, several previous studies also have revealed that a range of strategies can be useful for the development of digital literacy. Nisa & Setiyawati (2019) reported that methods used to improve digital literacy of high school students were lectures, discussions, playing video games, producing content for blogs, project-based learning, and interactive workshops. Besides, digital storytelling become one of the possible classroom activities, can facilitate students' digital literacy in higher education (Chan et al., 2017).

However, further research is needed to explore the effectiveness of different approaches to enhancing scientific and digital literacy simultaneously, particularly in the context of science education. Moreover, as stated by Dragoş & Mih (2015) that these two skills can be developed and improved through science learning. The learning design that is implemented should not only focus on content mastery and pedagogical knowledge but also need to be built on an online learning environment that requires various technological integration. It is in line with Vrana (2012), highlighting the Internet's role in providing access to scientific content and improving scientific literacy.

ERIC (Exploring-Resuming Integrated Criticizing) learning model was selected for its learning syntax, that is essential for accessing and using digital information during problem-solving. The ERIC learning model involves exploring activities, where students look for learning resources and then conduct a quick survey. In the following steps, students read in-depth, select and organize information more clearly as a summary, ask high-level questions, and discuss the problems in heterogeneous groups (Darmawan, 2021). Apart from that, the potency of this learning model can also be increased by combining content knowledge, pedagogical knowledge, and skills in using technology and information known as Technological, Pedagogical, and Content Knowledge (TPACK) to integrate technology effectively in encouraging the quality of learning. The learning design will also be implemented through lesson study activities to determine whether the learning model effectively improves the learning quality. Based on this description, the specific objectives of this research are: (1) analyze the influence of the ERIC learning model with the lesson study-based TPACK Framework on student Science and Digital literacy, and (2) analyze the contribution of lesson study implementation during ERIC learning to the professional development of educators.

METHODS

Research Design

This study uses mixed methods that combine quantitative and qualitative research. A concurrent mixed-method design was used in this study. Through this design, the advantages of each form of data can strengthen each other; that is, quantitative data provides generalizability, while qualitative data offers information about context or setting (Creswell, 2012). In-depth analysis through lesson study was conducted during the implementation of the Exploring-Resuming Integrated Criticizing (ERIC) learning model in a quasi-experimental setting with a pretest-posttest control group design. Two classes were chosen randomly in this study; one class was used as the experimental class, and the other was used as the control class. The quasi-experimental research design is presented in Table 1.

Table 1.
Quasi-Experimental Research Design

Class	Pretest	Treatment	Posttest
Experiment	O1	X1	O2
Control	O3	X2	O4

Descriptions:
O1, O3: pretest implementation
O2, O4: posttest implementation
X1: ERIC learning model with TPACK framework on lesson study
X2: Lecture-based learning

In this study, the ERIC learning model was implemented in the treatment group, while the control group implemented the lecture method. The ERIC learning model with the TPACK framework based on Lesson Study is presented in Table 2.

Table 2.
ERIC Learning Model with the TPACK framework based on lesson study

Technological knowledge (TK)	Pedagogical knowledge (PK)	Content knowledge (CK)
Knowledge about various types of technology as tools, processes, and resources. 1. Search for references from qualified resources or research articles (Indexed by Google Scholar, SINTA, Scopus) 2. Utilize the Learning	Knowledge of theory and practice in planning, process, and evaluation of learning. The ERIC learning model syntax includes: 1. Exploration of quality library sources and conducting a quick survey in each section (Exploring) 2. Summarizing information through in-depth study of the material, then asking high-level questions, and answering questions through	Knowledge about the content or teaching materials that will be taught to students. Science Concepts covering topics: 1. Plant cells 2. Plant tissue 3. Anatomy of dicot

Technological knowledge (TK)	Pedagogical knowledge (PK)	Content knowledge (CK)
Management System (ELITA) to access teaching materials and learning media, assignments, and quiz.	discussion in heterogeneous groups (Resuming Integrated Critizing) Implementation of lesson study includes the plan, do, and see stages.	and monocot plants

Population and Samples

This research was conducted at the Science Education Study Program, Faculty of Teacher Training and Education, Universitas Tidar. The sample was 70 first-year science education students taking Plant Structure and Function courses in the academic year of 2023/2024. The sample was determined by cluster random sampling from the four available classes and then used as one experimental and control class. The treatment group applied the ERIC learning model with the TPACK framework, while the control group implemented the lecture method. The research also involved three other lecturers during the implementation of lesson study to observe learning practices in class.

Instrument

Scientific and digital literacy data was measured using a questionnaire instrument with 5 Likert rating scales. The scientific literacy instrument was modified from Suwono et al. (2022) which contains 30 statements in six domains, covering the nature and function of science, science as human endeavor, habits of mind, interest in science, teaching scientific literacy, and ethics in science (Table 3). While the digital literacy instrument was modified from Baharuddin et al. (2021), consisting of 15 statements in three digital literacy domains, namely technical, cognitive, and social emotional domain (Table 4). The empirical validity and reliability of scientific and digital literacy instruments have been tested on 36 students. The results of the validity test using the Pearson Correlation revealed that all items of the scientific literacy instrument were valid with the sig value of 0.000-0.008 < 0.05, while the results of the reliability test using Cronbach's Alpha revealed that the instrument was reliable with sig value of 0.752. The empirical validity and reliability of the digital literacy questionnaire also showed that all test items were valid with a sig value of 0.000-0.031 < 0.05 and reliable with a sig value of 0.729.

Table 3.
Domains on the Scientific Literacy Questionnaire

No.	Domains	Item No.
1.	The nature and function of science	1,2,3,4,5,6
2.	Science as human endeavor	7,8,9,10,11
3.	Habits of mind	12,13,14,15,16
4.	Interest in science	17,18,19,20,21
5.	The teaching of scientific literacy	22,23,24,25,26
6.	Ethics in science	27,28,29,30

Modified from Suwono et al. (2022)

Table 4.
Domains on the Digital Literacy Questionnaire

No.	Domains	Item No.
1.	Technical	1,2,3,4,5
2.	Cognitive	6,7,8,9,10
3.	Social emotional	11,12,13,14,15

Modified from Baharuddin et al. (2021)

Procedure

The research was carried out through several stages. First, the preparation stage begins with a preliminary study to identify problems, identify the variables, select the sample, and develop research instruments. In the next step, the quasi-experimental study involving the implementation of ERIC learning model in the treatment group and lecture-based learning for the control group was conducted simultaneously with the implementation of the lesson study to collect qualitative data. This activity involves a group of lecturers collaboratively designing and implementing a lesson, observing its effects on student learning, and reflecting on the teaching process. Quantitative and qualitative data during the experimental and lesson study phases were then analyzed. Data collection technique includes field notes which recorded throughout the study; notes were taken during group collaborative and reflection sessions and observations of instruction. The schematic diagram of the research procedure is shown in Figure 1.

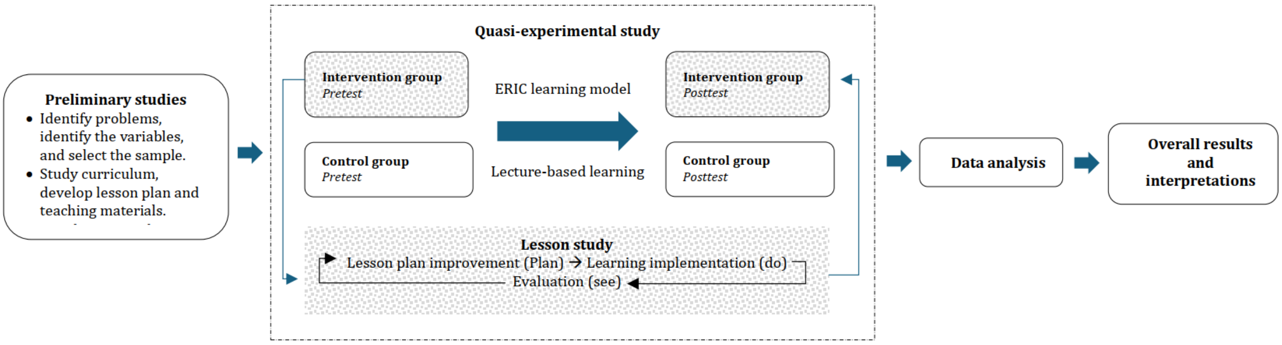

Figure 1. Research Procedure

Data Analysis Techniques

To reveal the effect of learning interventions on science and digital literacy, data was obtained from digital literacy questionnaires and science literacy tests during the pretest and posttest. The data was then tested using parametric inferential statistics using ANCOVA. Before this test was carried out, the authors first tested assumptions in the form of a normality test using One Sample Kolmogorov-Smirnov and data homogeneity using the Levene test. As shown in Table 5 and Table 6, the pretest and posttest data on scientific and digital literacy were normally and homogeneously distributed. Furthermore, to analyze the contribution of lesson study implementation to educators' professional development, the data obtained from field notes were recorded during observation of instruction and group collaborative and reflection sessions. The data was then analyzed and triangulated according to the Miles and Huberman model, starting from data reduction, data display, and drawing conclusions (Miles & Huberman, 1994).

Table 5.
Result for Normality.

Dependent variable	N	Kolmogorov-Smirnov	Asymp.Sig. (2-tailed)	Status of Data Distribution
Scientific literacy at pretest	70	0.072	0.200	Normal
Scientific literacy at posttest	70	0.085	0.200	Normal
Digital literacy at pretest	70	0.128	0.006	Normal
Digital literacy at posttest	70	0.089	0.200	Normal

Table 6. Result for Homogeneity

Dependent variable	F	df1	df2	Sig.	Status of Data Variance
Scientific literacy at pretest	0.726	1	68	0.397	Homogeneous
Scientific literacy at posttest	4,823	1	68	0.052	Homogeneous
Digital literacy at pretest	1.046	1	68	0.310	Homogeneous
Digital literacy at posttest	0.023	1	68	0.880	Homogeneous

RESULTS AND DISCUSSION

Based on the results of descriptive statistics in this study, it shows differences in students' acquisition of scientific literacy before and after learning. Based on the data, the average scientific literacy score that applied to the ERIC learning model with the lesson study based TPACK framework has increased with an initial score of 75.75 to 83.00 in the final results (see Table 7). Furthermore, the descriptive statistical results of the implementation of ERIC learning model with the Lesson Study-based TPACK framework on digital literacy increased with an initial score of 66.738 to 80.672 in the final results (see Table 8).

Table 7.
Results of Descriptive Statistics on Scientific Literacy

Treatment	X Science		Y Science	
	Mean	**Std. Deviation**	**Mean**	**Std. Deviation**
ERIC	75.755	9.04454	83.000	9.89892
LC	75.717	9.95677	78.729	9.10463

Table 8.
Results of Descriptive Statistics on Digital Literacy

Treatment	X Digital		Y Digital	
	Mean	**Std. Deviation**	**Mean**	**Std. Deviation**
ERIC	66.738	10.17463	80.672	7.30110
LC	66.667	9.12129	73.214	8.51726

The results of ANCOVA test are presented in Table 9. Based on the analysis, the significance values of the scientific and digital literacy variables were 0.021 and 0.000 respectively, smaller than 0.05. This indicates that there are significant differences of the students' science and digital literacy between the implementation of ERIC learning in experimental group and lecture based learning in control group.

Table 9.
The Summary of ANCOVA Results for Scientific and Digital Literacy

Source	df	Mean Square	F	Sig	Conclusion
Model* Scientific Literacy	1	315.367	5.619	.021	A significant effect
Model* Digital Literacy	1	962.094	28.377	.000	A significant effect

In line with the second problem of the study, analysis of qualitative data obtained from field notes during ERIC teaching observation sessions and collaborative sessions carried out by teachers during the reflection stage. It was conducted to reveal the contribution of implementing lesson study during ERIC learning to the professional development of educators. Based on the results of these observations and reflections (Table 10), the ERIC learning stages can enrich the learning experience of prospective teacher students and provide a more practical context in the use of technology and digital resources that are relevant to learning.

Table 10.
Summary of Observation Results and Reflections on ERIC Learning through Lesson Study Activities

Questions	Observer Findings
A. Are all students learning about current learning topics? How is their learning process?	Most students have studied well regarding the learning topic. In the exploring stage, students use devices to explore learning resources that support the problem-solving process through credible sources such as journal databases or e-books. Only 1 to 2 students still use Blogspot and practical reports that available on online during this activity. At the practical activity, each student participates in tasks such as preparing observation materials, making cross sections of leaves, or observing the results. Seating arrangements and the heterogeneous composition of group members based on their abilities facilitate communication between students. Through discussion, high-performance students can help students with low academic performance.
B. Which students cannot take part in learning activities today?	Student "Al" is from group 3, "St" is from group 1, and "Gt" is from group 5. These students don't pay attention to the lesson and are not involved in group discussions.
C. Why can't these students study well? In your opinion, what is the cause,	It is possible due to a lack of focus on learning, initiative to participate in the discussion process, and limited skills of microscopy skills, slide preparation from dissecting plant organs to examine internal structures. Teachers need to

Questions	Observer Findings
and what are alternative solutions?	review students' initial technical abilities and provide guidance.
D. How do lecturers try to encourage inactive students to study?	The lecturer guides each group periodically, provides direction regarding appropriate online literature search techniques, and adequately explains how to participate in observation activities and during the discussion process.
Reflection Results (What valuable lessons can be learned during the learning process): Through the ERIC learning stages, students can build good collaboration, use technology and digital resources effectively to expand understanding and participate actively during learning. However, guidance and motivation from lecturers for each group of students is necessary to ensure that the students actively involved in the learning process.	

The current research results show that quantitative and qualitative data provide supportive results to explain that the increasing of student engagement during ERIC learning contributes to prospective teachers' capacity to develop their scientific and digital literacy. Concerning the level of this contribution, the impact of the ERIC learning model was statistically significant for students' scientific and digital literacy. The significant impact of the course on scientific and digital literacy can be caused by the ERIC learning model, which is capable of constructing knowledge by emphasizing student involvement in problem-solving by sorting the information obtained. Klucevsek (2017) stated that it was important to always search and review literature to expand new vocabulary and develop understanding while asking questions, designing experiments, analyzing data, and doing research. Thus, technical domains of digital literacy on ERIC learning become an important part in understanding science as a process.

The ERIC learning model provides opportunities to use technology to complete assignments, provide necessary reading material, and present information for one's knowledge. The ERIC learning model has great impact on increasing scientific literacy because it can discipline students in reading and understanding material, thereby enabling students to search for material themselves, study problems more deeply, and be involved in finding and solving problems by criticizing them. According to Khotimah et al. (2023), problem-solving-oriented learning models can stimulate the discovery of scientific concepts through information exploration, analyzing problems by understanding information to determine its meaning, and the ability to evaluate and synthesize information by determining relevance so that they can connect the information through arguments or make conclusion.

ERIC learning model provides flexibility for students to study according to their needs so that they can understand scientific concepts and apply them wisely in everyday life so they can adapt quickly to changing times. The ERIC learning model optimizes scientific literacy according to 21st-century learning skills such as mastering knowledge, thinking critically and creatively, and communicating and collaborating effectively. According to Putra et al. (2016), science learning activities can be ideal and in-depth if they can train their scientific literacy, such as scientific investigations that build knowledge independently, thereby helping to develop an understanding of representative concepts. In line with Suwono et al. (2017), applying the problem-based learning model must be solved using scientific process skills and scientific thinking to foster critical thinking and train knowledge development to increase scientific literacy.

The main focus of digital literacy that science teachers must master in learning is problem-solving and building knowledge through technology critically, flexibly, and ethically (Rizal et al., 2019). Teacher skills in digital literacy emphasize operational abilities in using digital tools, the ability to search for information through digital media, and social-emotional abilities in operating digital tools and media (Baharuddin et al., 2021). ERIC learning increase students' digital literacy due to continuous learning activities and the habit of seeking information related to material and facilitating a learning ecology to access information through digital technology actively. By this, it is expected that they could develop a wide range of skills for searching, identifying, critical evaluation, and using information for more independent and creative behavior in the digital environment.

Learning models that can develop and apply digital literacy to solve complex problems can improve students' pedagogy through technology (Angraini et al., 2022). The ERIC learning model, which pivots on 21st-century learning, can meet students' knowledge needs following current developments in information and technology. In line with Chaiyama (2019), learning models that develop learning skills in the 21st century have digital literacy abilities, especially literacy in processing information through various media and learning resources from internet technology so that they can present information and develop material in accordance with the concepts being studied.

Implementing the ERIC learning model combined with the TPACK framework through lesson study improves the quality of learning. Using the ERIC model with a lesson study-based TPACK framework helps students integrate knowledge into science learning activities. The TPACK framework with a problem-solving learning model can encourage students to solve problems effectively in the learning process (Irmita & Atun, 2018). Using the TPACK framework in learning planning also effectively builds communication and discussion skills during the learning process (Nurdiani et al., 2019).

Using the TPACK framework in lesson study activities to implement the ERIC learning model can empower the science and digital literacy of prospective teachers. The TPACK framework can help teachers implement 21st-century learning, integrating technology to improve learning and problem-solving skills (Nurdiani et al., 2019). The ERIC model using the TPACK framework in learning can develop students' scientific and digital literacy because it makes it easier for students to interpret scientific data and information in accordance with basic biological concepts. Increasing scientific literacy is also achieved through discussion activities, which allow students to explain scientific phenomena by collecting information and scientific evidence (Irmita & Atun, 2018). Implementation of a learning model by combining TPACK in lesson plans can integrate digital literacy effectively because it empowers technology, pedagogy, and content to support learning, such as the skills of digital media especially for searching, working on, evaluating, and using it intelligently and carefully (Schmid et al., 2021).

Collaboration with peers on learning objectives, teacher instruction, and worksheets with peers helps teachers learn new approaches to teaching students. After planning collaboratively for the first research lesson, participants indicated a desire to continue the collaborative session. Teachers indicated that group planning was very beneficial. This finding is in line with Rock & Wilson (2005) that lesson study is very useful for new teachers in North Carolina.

The limitation of this research lies in the data collection time, which was limited to four weeks of learning implementation. To develop students' skills more optimally, data collection should be carried out over a longer duration. This is because acquiring and improving skills is a complex process involving the types of learning strategies applied and specific skills developed. Therefore, while enhancing skills may require more time, the specific time frame can vary depending on the nature of the skill and the individual's learning process.

CONCLUSION

In conclusion, the results of this analysis provide compelling evidence that the ERIC learning model, in conjunction with the TPACK framework and lesson study activities, holds great promise for enhancing scientific and digital literacy. By implementing lesson study practices during the ERIC learning, teachers can play a pivotal role in nurturing prospective teachers to be digitally literate and scientifically competent. These findings have practical implications for educators seeking effective approaches to improve the quality of learning experiences for their students.

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