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TPACK-based Active Learning to Promote Digital and Scientific Literacy in Genetics

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ABSTRACT

Active learning is centered on students and encourages them to participate in various classroom activities, with the teacher as a facilitator. Students are expected to develop multiple 21st-century skills through an active learning process, including digital and scientific literacies. Numerous studies demonstrate that students lack digital and scientific literacy, necessitating the empowerment and improvement of both skills through active learning based on TPACK (Technological, Pedagogical, and Content Knowledge) (Tütüniş et al, 2022). The objective of this study was to investigate the effect of TPACK-based active learning on students' digital literacy and scientific literacy in Genetics. PBL (Problem-based Learning), RQA (Reading, Questioning, and Answering), and a mix of PBL and RQA are all examples of active learning approaches. TPACK-based active learning was used in the Genetics course because students perceive genetics as challenging. A pretest-posttest three-treatment design was adopted, with each learning model being applied to a group of students. This study uses parametric inferential statistical methods, using ANCOVA. Data on students' digital literacy and scientific literacy were obtained using pretest and post-tests. The results indicated no statistically significant difference between the three learning models. The students' digital literacy and scientific literacy both experienced an increase due to implementing the three learning models. The implications of this research are the three active learning models based on TPACK can promote students' digital and scientific literacies. Other educators can adopt the experience of teaching Genetics with PBL, RQA, and PBL-RQA to promote digital literacy and scientific literacy.

Keywords: active learning, digital literacy, Genetics, scientific literacy, TPACK

INTRODUCTION

Industrial revolution 4.0 has changed the way of thinking and innovation in education (Shahroom & Hussin, 2018). The improvements required to prepare for Industrial Revolution 4.0 begin with determining how to improve student competencies and maximize their potential, particularly in performing the 21st-century skills (Gamar et al., 2018). Educators must be able to reinvent curricula, methodology, material, and assessments to provide millennial generations with the necessary qualifications and the 21st-century skills to compete worldwide (Care et al., 2018; Ghozali & Tamansiswa, 2018).

Digital and scientific literacy are critical abilities for navigating the fourth industrial revolution in the twenty-first century. Various studies show that students' digital literacy and scientific literacy are still low. For example, students from the science department have a technology-savvy background but fail to use technology for learning purposes and academic improvement (Tewari & Birla, 2018; Vuran et al, 2020). In Indonesia, the digital divide requires digital literacy education delivered through several knowledge transfer mechanisms involving educators, students, and parents (Rahmah, 2015). While the level of scientific literacy skills can be categorized as sufficient, overall, students' scientific literacy level is not satisfactory (Adi et al., 2020). In the third year, the scientific literacy of students majoring in Biology, State University of Malang, the level of scientific literacy was higher than in the first year. However, the literacy level of third-year students is not satisfactory, so there needs to be a change in teaching and learning strategies (Suwono & Furaidah, 2016).

Not only is digital literacy essential for involvement in education, work, and other facets of social life, but it is also helpful for acquiring diverse understandings in all sectors of life (Levano-Francia et al., 2019). Digital literacy refers to the knowledge, skills, and attitudes that enable individuals and communities to survive, prosper, and grow in an increasingly digital world (Traxler, 2018). Digital literacy is becoming a more integral and visible component of education

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(Cassidy et al., 2019). Access to technology and a focus on digital literacy provide ample opportunity for future learners to flourish (Statti & Torres, 2020).

Digital literacy applied to the regular classroom and home learning will positively affect students' learning processes (Greene, 2018; Heider & Jalongo, 2014; Karpati, 2011). Learners who understand the value of digital literacy will utilize information and communication technology more prudently and will be better equipped to control their learning (Heider & Jalongo, 2014). Enhancing a person's digital literacy enables him to adjust to a new environment more easily. Utilizing the possibilities of digital technology offers may also improve science learning. Students' interest in and knowledge of technology and its influence on learning stimulate and encourage the growth of their scientific literacy (Ng, 2012).

Scientific literacy refers to an individual's capacity to comprehend, convey, and use scientific knowledge to solve problems involving natural phenomena or diverse circumstances in the real world (Gormally et al., 2012). Scientific literacy refers to a student or adult's ability to apply scientific knowledge to real-world cases. It can also be defined as the capacity to evaluate the quality of scientific information and arguments using evidence and data (Dragoş & Mih, 2015). College students are expected to have a high level of scientific literacy, as science pervades modern life. Every action in every subject uses science and technology (Espinosa, 2005). Scientific literacy is critical in the twenty-first century due to the numerous difficulties associated with research and technology (Holbrook & Rannikmae, 2009; Turiman et al., 2012). Scientific literacy is necessary because it enables students to comprehend the potential and misuse of science, make decisions about everyday situations based on basic information and choose from various concerns that require scientific understanding (Jgunkola & Ogunkola, 2013).

Digital literacy and scientific literacy are skills that can be developed and enhanced. Students' digital literacy can be improved by using technology devices such as computers, mobile phones, tablets, the Internet, and social media in the classroom and in extracurricular activities (Çam & Kiyici, 2017). Education requires a framework for integrating digital literacy information and skills into virtual and physical classrooms (Greene, 2018). The development of digital literacy can be accomplished by instructors' initiatives to teach students by applying digital competencies to solve complicated problems, providing students with access to technology, and enhancing pedagogy through technology (English, 2016). The virtual world of media can be interwoven into education to help students develop scientific literacy and a sense of humour (Corbit et al., 2005). Students' scientific literacy can be strengthened and enhanced through university-level science instruction (Shaffer et al., 2019). Education across disciplines must develop techniques for assessing students' knowledge of scientific literacy application. The online learning environment necessitates various technologies, including appropriate e-learning resources that can be accessed anywhere and anytime, and can help students enhance their scientific literacy (Risniawati et al., 2020).

Technological, Pedagogical, and Content Knowledge (TPACK) provide educators with the foundation necessary to integrate technology effectively into the learning process (Joy, 2015; Rosenberg & Koehler, 2015; Novo et al., 2016). TPACK is a framework that encompasses three distinct components: content knowledge, pedagogy, and technology. TPACK is a solution that may be used for online and offline classroom instruction (Brown & Neal, 2011; Rosenberg & Koehler, 2015). TPACK involves the interrelationships between various knowledge domains and determines essential aspects of educator knowledge. Multiple knowledge domains are required when educators integrate technology into their teaching practice. TPACK significantly affects educators' performance expectancy and effort experience (Mohammad-Salehi et al., 2021). TPK, TCK, and PCK are supporting factors in the development of TPACK (Mohammad-Salehi & Vaez-Dalili, 2022). TPACK is expected to help a student's skill development and to include the primary components necessary for successful online learning education (Corbit et al., 2005). Appropriate technology for acquiring relevant topic knowledge is critical for learning. Appropriate technology effectively enhances students' diverse abilities and academic achievements (Atun & Usta, 2019). Numerous university courses, for example, Genetics, a course offered by the biology department, require a TPACK framework.

Based on the content, Genetics is a relatively complicated subject for students. This difficulty is because Genetics comprises extremely complex instructional materials, abstract concepts, and difficult-to-understand terminology, which results in students occasionally developing misconceptions regarding terms used in Genetics courses (Fauzi & Fariantika, 2018; Fauzi & Ramadani, 2017; Johnson & Jackson, 2015; Murray-Nseula, 2011)with neuropsychological indicators usually being related to subjects with other forms of neurological damage. In this study we assessed the performance of 74 subjects with frontal lobe epilepsy (42 with left, 32 with right frontal epileptic foci. One of the most perplexing topics to study in Genetics is Mendel's suggested inheritance of characteristics. Trait inheritance confuses pupils when analyzing and researching the causes (Redfield, 2012). Genetics is also a challenging subject for students majoring in biology at Universitas Negeri Malang in Indonesia, mainly comprehending the substance of knowledge regarding the function or expression of genetic material, genetic material modifications, and genetic engineering. As a result, educators at the institution always strive to implement learning methodologies that are believed to boost students' diverse skills through active learning.

Active learning enables pupils to participate actively in the learning process (Lombardi et al., 2021). Active learning is a method that involves students in a dynamic and enjoyable learning environment. It can be done in various ways, including discussion/group work, metacognition, formative assessment, worksheets, practice, and games (Driessen et al., 2020)but the term is not well-defined in the context of undergraduate biology education. To clarify this term, we explored how active learning is defined in the biology education literature (n = 148 ar-ticles. Active learning is a process in which students participate actively in various activities that challenge them to reflect on and apply diverse ideas while periodically reviewing their comprehension and ability to deal with concepts or difficulties encountered in specific disciplines (Michael, 2006).

Active learning is one of the approaches educators use to increase student involvement in the classroom, laboratory, or field experience (Lombardi et al., 2021). Active learning encourages learners to participate actively in the learning process, enabling them to acquire knowledge more quickly and retain it longer (Phillips, 2005). Active learning implemented by educators usually involves a variety of pedagogical methods. It is student-centred, encouraging students' involvement through collaboration, problem-solving, experimentation, and writing activities (Cavanagh et al., 2018). Active learning has increased student performance in science, engineering, and mathematics (Freeman et al., 2014).

Several learning models in active learning strategies are PBL (Problem-based Learning) and RQA (Reading, Questioning, Answering). The PBL and RQA learning models have been applied in various universities, including Universitas Negeri Malang. PBL is an active learning approach that focuses on solving real-world issues (Hartman et al., 2013), whereas RQA includes reading and questioning. Reading and questioning are activities that assist students in comprehending concepts, expanding previously held knowledge, connecting disparate ideas across students, and eliciting new ideas (Hariyadi et al., 2017). In this study, educators tried to combine the two learning models into PBL-RQA. The combination of PBL-RQA provides opportunities for students to practice independent learning. It encourages them to be more disciplined and diligent in their pursuit of additional facts about a learning topic and gain a broader perspective on various problems through reading and formulating questions (Bahri et al., 2019)and has not attempted to empower students' metacognitive skills. This research was a quasi-experimental study that aims to find out the influence of PBLRQA strategy on the metacognitive skills of students with different academic achievement in the study of animal physiology. This study used a pretest-posttest non-equivalent control group design. The sample of this study was the third year biology students as many as 115 people distributed in 4 groups. The experimental group was taught by using PBLRQA strategy and the control group was taught by traditional learning, each represented by two classes. Student cognitive retention is measured by essay questions. The research data were analyzed using descriptive and inferential statistics with two-ways covariate analysis (ANCOVA.

During the COVID 19 pandemic, Universitas Negeri Malang has conducted PBL and RQA learning online using SIPEJAR (Learning Management System owned by the university), Zoom Meeting, and Google Meet. However, the combined learning model (PBL-RQA) has never been implemented offline or online. Whether the three modes of instruction (PBL, RQA, and PBL-RQA) can empower and improve students' digital literacy and scientific literacy is unknown. This study aimed to examine the effect of TPACK-based active learning (PBL, RQA, and PBL-RQA) on the digital literacy and scientific literacy of university students enrolled in a Genetics course. The research hypothesis is that TPACK-based active learning (PBL, RQA, and PBL-RQA) can help students improve their digital and scientific literacy.

METHOD

Research Design

The research design used in this study is the pretest-posttest three treatment design (adapted from Cohen et al., 2018) (Table 1). Active learning using the TPACK framework was conducted synchronously and asynchronously in three Genetics classes. Although all three classes employed TPACK-based learning, the learning models used varied. Each class was divided into nine groups. The groups were formed based on the students' prior knowledge of Genetics and the availability of online learning support equipment, such as cellphones and computers, owned by the students. The learning process in this study is presented in Table 2.

Respondents

The respondents of this study were six classes of fourth-semester students who were enrolled in the Genetics course at the biology study program, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Indonesia. The classes were tested for homogeneity by using their initial scores in Genetics. When the homogeneity test revealed that all classes

Table 1: Research Design

Pretest	*Treatment*	*Post-test*
O1	X1	O2
O3	X2	O4
O5	X3	O6

Remarks:
X1 : TPACK-based PBL
X2 : TPACK-based RQA
X3 : TPACK-based PBL-RQA
O1, O3, O5 : Pretest
O2, O4, O6 : Post-test

Table 2: TPACK-based Active Learning Processes in the Treatment Groups

No.	*Group*	*Technological (T)*	*Pedagogical (P)*	*Content Knowledge (CK)*
1.	TPACK-based PBL	Synchronous discussion through Zoom Meeting or Google Meet Asynchronous: WhatsApp Group Task submission via: SIPEJAR/Google Classroom Digital literacy statements and scientific literacy tests distributed via Google Form Videos: YouTube Virtual Laboratory from Oxford University	**The stages of learning in PBL class:** **Asynchronous** *First*, orienting students to problems *Second*, organizing students into groups *Third*, assisting group investigation **Synchronous** *Fourth*, students develop and present the investigation results through a group presentation *Fifth*, students analyze and evaluate the problem-solving process	(1) Content Knowledge of Genetics covers the following topics: (2) topics covered in Genetics 2 course (3) Regulation of gene expression in prokaryotic organisms (4) Regulation of gene expression in eukaryotic organisms (5) Genetic control of immune response (6) Genetic control of cell division (7) Genetics of sex expression, one gene-one enzyme hypothesis, gene work interaction (8) Definition, enzymes, and specifics of recombination (9) Transformation and transduction in bacteria, conjugation in bacteria, and recombination in bacterial phages (10) The genetic material in the population; Genetic Engineering as a form of application of Genetics in modern biotechnology
	TPACK-based RQA	Technology used is similar to that employed in the TPACK-based PBL classroom	**The stages of learning in RQA class:** **Asynchronous** *First*, students read a text and write a summary from the reading material *Second*, students formulate questions *Third*, students answer the questions **Synchronous** *Fourth*, students are involved in a discussion *Fifth*, students do a review of the material being learned	The topics are identical to those of the TPACK-based PBL.
3.	TPACK-based PBL-RQA	The technology used is similar to that employed in the TPACK-based PBL classroom	**The stages of learning in PBL-RQA class:** **Asynchronous** *First*, orienting students to problems and leading students to literature reading and summary writing *Second*, students formulate questions on the reading material as the problem source and create temporary answers to the questions *Third*, organizing students to learn **Synchronous** *Fourth*, assisting students' group investigation and discussion *Fifth*, students develop and present the investigation results through a group presentation *Sixth*, students analyze and evaluate the problem-solving process	The topics are identical to those of the TPACK-based PBL.

were homogeneous, three were randomly chosen as treatment classes. The three treatment groups that implemented TPACK-based active learning models are a PBL class with 23 students, a RQA class with 26 students, and a PBL-RQA class with 20 students.

Data Collection and Research Instrument

Data on Students' Digital Literacy

Data on the students' digital literacy were gathered using a questionnaire built on the digital literacy indicators suggested by Kaeophanuek et al. (2018). The digital literacy indicators consist of information skills, skills in utilizing digital tools, and skills in digital transformation. The digital literacy questionnaire consists of 37 statements consisting of 20 positive statements and 17 negative statements (Table 3).

The Pearson Product Moment correlation was used to determine the empirical validity of the questionnaire items, and Cronbach's Alpha was used to determine the questionnaire's empirical reliability. The empirical validity of the questionnaire items revealed that four of the 37 questionnaire statements were invalid (statements 4, 15, 18, and 31). The invalid statements were not included in either the pretest or post-test. Furthermore, Cronbach's Alpha value of 0.89 suggested that 33 statement items were highly reliable.

Data on Students' Scientific Literacy

The participants' scientific literacy was measured using a multiple-choice test containing 24 items constructed on the scientific literacy indicators adopted from Gormally et al. (2012) (Table 4). The empirical validity of the scientific literacy test items revealed that two of the twenty-four items (questions 11 and 21) were invalid. Invalid questions would be omitted from both the pretest and post-test. Cronbach's Alpha value of 0.69 indicated that 22 items of the test had a good level of empirical reliability. The empirical validity and reliability tests on the digital literacy statements and scientific literacy questions suggested that the instruments were appropriate for assessing students' digital and scientific literacy. Pretest (before learning) and post-test (after learning) were used to obtain

Data Analysis

Analysis of Covariance (ANCOVA) was utilized for statistical analysis in this study. The research hypotheses were tested using ANCOVA at a significance level of 5%. The data would be subjected to additional analysis using the LSD (Least Difference Significance) test if the result was significant. Before doing ANCOVA, the data must be normally distributed with a homogenous variance. The Levene test was used to determine the homogeneity of the data, and the Kolmogorov Smirnov test was used to determine the normality of the data with a significance level of $p > 0.05$.

The pretest and post-test statistics for digital literacy can be found in Table 5. The homogeneity test findings for the digital literacy pretest and post-test indicated a significant $p > 0.05$, namely 0.055 for the pretest and 0.33 for the post-test (homogeneous data). The normality test revealed a significance

Table 3: Blueprint of the Digital Literacy Questionnaire

No.	*Indicator*	*Item No.*	*Positive Statement*	*Negative Statement*
1.	Information Skills	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	2, 3, 6, 7, 8, 11, 14	1, 4, 5, 9, 10, 12, 13
2.	Skills in utilizing digital tools	15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27	15, 16, 17, 19, 22, 24, 25, 27	18, 20, 21, 23, 26
3.	Skills in digital transformation	28, 29, 30, 31, 32, 33, 34, 45, 36, 37	29, 30, 32, 35, 37	28, 31, 33, 34, 36

Source: Modified from Kaeophanuek et al. (2018)

Table 4: Blueprint of the Scientific Literacy Test

No.	Indicator	Sub-Indicators	Item No.
1.	Understand the methods of inquiry that lead to scientific knowledge.	Identify valid scientific arguments.	1, 2, 3
		Evaluate source validity.	4, 5, 6
		Evaluate the use and misuse of scientific information.	7, 8, 9
		Understand the elements of research design and how they influence scientific findings/conclusions.	10, 11, 12
2.	Organize, analyze, and interpret quantitative data and scientific information.	Create graphical representations of data.	13, 14
		Read and interpret graphical representations of data.	15, 16
		Solve problems using quantitative skills, including probability and statistics.	17, 18, 19
		Understand and interpret basic statistics.	20, 21
		Justify, predict, and draw conclusions based on quantitative data.	22, 23, 24

Source: Gormally et al. (2012)

value of 0.08 for the pretest and 0.20 for the post-test on digital literacy (normally distributed data).

The assessment scale for the scientific literacy tests in multiple-choice questions is that each correct answer is worth 1 and each incorrect answer is worth 0. The scientific literacy tests showed a significance level of p > 0.05, with a significance value of 0.65 for the pretest and 0.20 for the post-test (homogeneous data). The pretest for scientific literacy yielded a significance value of 0.20, whereas the post-test for scientific literacy yielded a significance value of 0.21 (normally distributed data).

FINDINGS

Digital Literacy

Students' digital literacy has increased due to TPACK-based active learning in Genetics classes using various learning models (PBL, RQA, and PBL-RQA) (Figure 1). The significance value for students' digital literacy in the three classrooms is 0.17 (p-value > 0.05), indicating no difference in students' digital literacy scores across the three classes. In other words, all treatment groups increased their digital literacy in the same way (Table 6). Based on the LSD (Least Difference Significance) test result, the three treatment groups using TPACK-based active learning models (PBL, RQA, and PBL-RQA) were not significantly different in improving students' digital literacy (Table 7).

Scientific Literacy

Students' scientific literacy has increased due to TPACK-based active learning in Genetics classes using various learning models (PBL, RQA, and PBL-RQA) (Figure 2). The significance value for students' digital literacy in the three classrooms is 0.25 (p-value > 0.05), indicating that there was no difference in students' scientific literacy scores across the three treatment groups (Table 8). Based on the LSD (Least Difference Significance) test result, the three treatment groups using TPACK-based active learning models (PBL, RQA, and PBL-RQA) were not significantly different in improving students' scientific literacy (Table 9).

Table 5: Digital Literacy Test Assessment Scale

Assessment Scale	
Positive Statements	*Negative Statements*
1: I never do it	5: I never do it
2: I sometimes do it	4: I sometimes do it
3: I often do it	3: I often do it
4: I do it very often	2: I do it very often
5: I always do it	1: I always do it

DISCUSSION

This study aimed to determine the impact of TPACK-based active learning with the three PBL, RQA, and PBL-RQA models on students' digital literacy and scientific literacy in the Genetics course. The results obtained are that TPACK-based active learning using PBL, RQA, or PBL-RQA can improve students' digital and scientific literacy (Figure 1 and Figure 2). The three TPACK-based active learning classes, namely PBL, RQA, and PBL-RQA, can be used as choices in Genetics learning. This result is possible because each learning model possesses beneficial qualities for learning. Problem-based Learning (PBL) effectively trains students to solve and find solutions to a Genetic problem found in everyday life. Students are expected

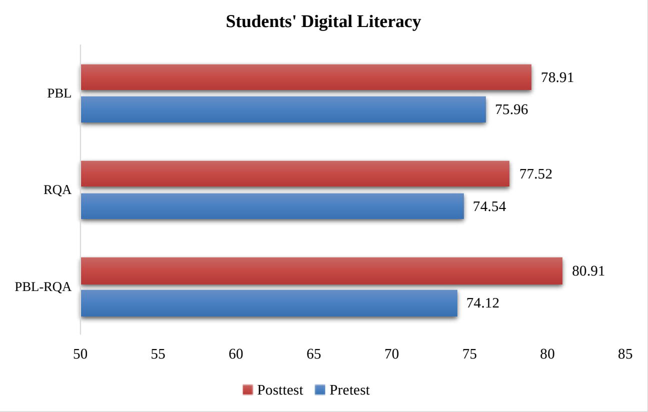

Fig. 1: Students' Digital Literacy Following the Implementation of TPACK-based Active Learning in Genetics classes

Table 6: The Result of ANCOVA Analysis on the Effect of TPACK-based Active Learning on Students' Digital Literacy

Source	*Type III Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*	*Partial Eta Squared*
Corrected Model	998.03a	3	332.67	7.84	.00	.26
Intercept	1918.83	1	1918.83	45.25	.00	.41
Pretest	868.79	1	868.79	20.49	.00	.24
Group	151.81	2	75.91	1.79	.17	.05
Error	2756.09	65	42.40			
Total	434081.54	69				
Corrected Total	3754.12	68				

R Squared = .266 (Adjusted R Squared = .232) to search for various information using various technologies and deepen their knowledge of the problem. Students are trained to read and ask questions through the Reading, Questioning, Answering (RQA) stages. The habit of reading and asking questions is anticipated to stimulate students' curiosity and increase their capacity for knowledge construction. The advantages of combining PBL and RQA are that they expose students to real-world situations. Additionally, the PBL-RQA combination incorporates phases of reading and questioning to help students comprehend challenges in a more organized, clear, and directed manner.

Problem-based Learning (PBL) focuses on the learner's experience and underscores the importance of active learning. Another general principle of PBL is the change in the role of educators to facilitators/mentors/trainers (Miller, 2004). Active learning is a defining feature of PBL classrooms in the twenty-first century, where students are more involved and active in their learning than passive observers. Problem-based learning, like cooperative learning, is built on group collaboration and solidarity (Akinoğlu & Tandoğan, 2007). The best way to build 21st-century skills is through hands-on, problem-solving activities such as Problem-based Learning. The strong connection between 21st-century skills learning and PBL equips modern classrooms (offline and online) with various learning facilities. PBL is designed so that students can achieve maximum learning outcomes and develop the skills necessary for success in the workplace (Lapek, 2018). Problem-based learning also effective increase academic achievement, learning motivation, and develop career interests significantly (Çevik, 2018; Kılıç & Moralar, 2015). Classes that follow the RQA approach benefit students' cognitive aspects by increasing their higher-order thinking skills as they progress through reading and asking questions (Hariyadi et al., 2017). Additionally, RQA has been shown to boost students' independence, motivation to study, and cognitive learning outcomes. Additionally, the RQA learning model requires students to participate actively in the learning process, both individually and in groups, such as via discussion forums. (Bahri & Corebima, 2015).

Table 7: Digital Literacy Mean Scores in Three Treatment Groups using TPACK-based Active Learning

No.	*Group*	*Mean Score*	*LSD Notation*
1.	TPACK-based RQA	77.67	**a**
2.	TPACK-based PBL	78.46	**a**
3.	TPACK-based PBL-RQA	81.23	**a**

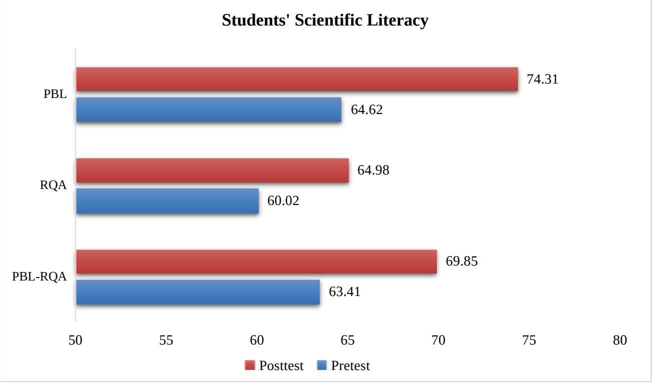

Fig. 2. Students' Scientific Literacy Following the Implementation of TPACK-based Active Learning in Genetics classes

The combination of PBL with RQA is premised on Allen et al. (2001) that problem-based learning is more effective when paired with RQA, which allows students to participate in class discussions through class presentations. The stages of PBL-RQA expose students to unstructured situations from the real world to identify these problems and resolve them by reading various sources such as books and articles (Bahri et al., 2019)and has not attempted to empower students' metacognitive skills. This research was a quasi-experimental study that aims to find out the influence of PBLRQA strategy on the metacognitive skills of students with different academic achievement in the study of animal physiology. This study used a pretest-posttest non-equivalent control group design. The sample of this study was the third year biology students as many as 115 people distributed in 4 groups. The experimental group was taught by using PBLRQA strategy and the control group was taught by traditional learning, each represented by

Table 8. The Result of ANCOVA Analysis on the Effect of TPACK-based Active Learning on Students' Scientific Literacy

Source	*Type III Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*	*Partial Eta Squared*
Corrected Model	5990.88a	3	1996.96	9.51	.00	.30
Intercept	6111.05	1	6111.05	29.10	.00	.30
Pretest	4923.35	1	4923.35	23.45	.00	.26
Group	583.55	2	291.77	1.39	.25	.04
Error	13645.70	65	209.93			
Total	352993.34	69				
Corrected Total	19636.59	68				

a. R Squared = .305 (Adjusted R Squared = .273)

Table 9. Scientific Literacy Mean Scores in Three Treatment Groups using TPACK-based Active Learning

No.	*Group*	*Mean Score*	*LSD Notation*
1.	TPACK-based RQA	66.28	a
2.	TPACK-based PBL-RQA	69.40	a
3.	TPACK-based PBL	73.24	a

two classes. Student cognitive retention is measured by essay questions. The research data were analyzed using descriptive and inferential statistics with two-ways covariate analysis (ANCOVA. However, to maintain the benefits of PBL and RQA learning models in PBL-RQA, educators must be able to design them based on student needs.

Educators who can modify curriculum, content, pedagogy, and assessment in the classroom can accommodate students' various 21st-century skills (Care et al., 2018; Ghozali & Tamansiswa, 2018)collaboration, critical thinking, and communication. The focus on these "21st century goals" is visible in education and curricular reform, and has been promoted by global discussion of changing work and societal needs. This paper describes global, regional, and national examples of this shift, and then focuses on implementation challenges. The paper focuses most explicitly on the issue of assessment but asserts that any major reform in an educational philosophy shift must ensure alignment across the areas of curriculum, pedagogy, and assessment. The paper identifies several challenges to implementation of this educational shift. These include the need for clear understanding of the necessary skills—beyond mere identification of definition and description. This is essential if education systems are to reform curricula to integrate the new learning goals that the skills imply. A second challenge is the need for clear descriptions of what different levels of competencies in skills might look like. Although a few education systems have developed early frameworks which include increasing levels of competency, there are no generic examples that describe how some of these skills "progress." Such descriptions would enable teachers to know what to reasonably expect of a child in the early years of elementary school versus of a child in later years in terms of collaborative behavior or critical thinking. A third challenge lies in the obstacles that these first two hurdles pose to the development of assessments of 21st century skills (21CS. The educator's requirement for empirical data on pedagogy in online learning is critical, as online learning design must emphasize pedagogy rather than being driven solely by technology (Çakýrodlu, 2014). Specific disciplines, delivery methods, and instructional tactics employed by educators will affect the abilities and knowledge of students, ensuring the success of online learning (Lee & Hirumi, 2004). Creating efficient learning strategies is necessary to promote the transmission of knowledge or topic knowledge to students in online learning (Holden et al., 2010)educators and trainers are challenged within their respective organizations to provide for the efficient distribution of instructional content using instructional media. The appropriate selection of instructional media to support distance learning is not intuitive and does not occur as a matter of personal preference. On the contrary, instructional media selection is a systematic sequence of qualitative processes based on sound instructional design principles. Although media selection is often mentioned when studying the discipline of instructional technology or Instructional Systems Design (ISD.

Online learning settings can employ active learning practices that are not limited to the traditional classroom setting (Banayo & Barleta, 2022; Brown, 2014; Hatta et al., 2020; Kuo & Kuo, 2015). Active learning supportive practices are frequently based on problem-solving, creative thinking, and research-based, issue-based, and project-based (Seechaliao, 2017). Active learning must be tailored to students' characteristics to assist them in developing future competencies (Kuo & Kuo, 2015). Active learning strategies that will be applied in the classroom must align with the learning objectives (Hatta et al., 2020).

Active learning in an online context necessitates the implementation of a TPACK framework (Doering et al., 2009). Technology and educator pedagogy can be established in accordance with learning objectives so that students obtain the necessary skills and comprehension, as well as a strong integration of technological, pedagogical, and content knowledge (Rahmawati et al., 2019). The quality of online learning is determined by how technology, pedagogy, and content knowledge are integrated (Chai et al., 2014). If educators have a greater understanding of technology, pedagogy, and content and the connections between these areas of knowledge, they will be able to construct more appropriate and successful learning environments (Chai et al., 2014; Finger & Finger, 2013; Knolton, 2014). Educators in Genetics education require unique technology, pedagogy, and content knowledge (Aivelo & Uitto, 2018). There was a significant association between TPACK and several types of learning methods, including peer learning, elaboration, organization, critical thinking, and self-metacognitive learning (Gündoğmuş & Gündüz, 2015).

In this study, the technology in TPACK used in synchronous and asynchronous learning processes is Zoom Meeting, Google Meet, SIPEJAR (Learning Management System owned by Universitas Negeri Malang), and WhatsApp Groups. Students also used the virtual laboratory application from Harvard University and YouTube videos to acquire in-depth knowledge of genetic content, especially applied genetics. Learners must utilize a variety of technological apps to comprehend the learning content (Atun & Usta, 2019). Online education via multiple platforms demands more preparation than face-to-face lectures (Wang, 2021). Synchronous virtual classroom systems enable a high degree of interactivity for distance education programs (Schullo et al., 2007). Online classes can help students develop digital literacy (Novo et al., 2016) and scientific literacy skills (Corbit et al., 2005; Risniawati et al., 2020)the Cornell Theory Center (CTC).

CONCLUSION

Active learning is learning centered on participants to be more involved in the learning process. PBL, RQA, and PBL-RQA are some learning models used in active learning. According to the study's findings, TPACK-based active learning in the Genetics class using PBL, RQA, and PBL-RQA could enhance their digital and scientific literacies. Hence, those three active learning models can be recommended for educators to promote digital and scientific literacy. In addition, the three learning models can be used as an alternative in teaching Genetics which is a relatively difficult subject for students.

LIMITATION

It is well established that the three TPACK-based active learning models, PBL, RQA, and PBL-RQA, can help students enhance their digital and scientific literacy. Therefore, all three can be used as alternatives to Genetics instruction. However, each learning model confronted unique implementation challenges in practice. Students in the RQA class read only the references provided by the lecturer. It appears as though the learners lacked the initiative to seek out additional reading materials. Students in a PBL class frequently struggled to discover solutions to assigned problems. Students spent significantly more time in the PBL-RQA class than they did in PBL or RQA because they must go through the lengthy stages of PBL-RQA. The stages of PBL-RQA require the students to read, summarize, pose pertinent questions about the provided problem, develop preliminary answers, discuss, present, and analyze and evaluate the problem-solving process. The technological implementation of the TPACK-based active learning process also has limitations. Barriers such as slow internet that did not enable video conferencing frequently impaired the efficiency of learning time, even more so when learning was conducted synchronously via Zoom Meeting or Google Meet.

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ETHICS AND CONFLICTS OF INTEREST

Before conducting the research, the researcher had asked permission from the University and Study Program where the data was collected. Students who participated in this study volunteered to contribute data, and the researcher will maintain the participants' anonymity. This study contains no potential conflicts of interest.

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