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Effectiveness of RFDT learning based on TPACK framework in improving the critical and creative thinking abilities of prospective biology teacher students

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Abstract

The emphasis on 21st-century skills, particularly critical and creative thinking, has driven educational advancements, including technology integration through frameworks like TPACK (Technological Pedagogical Content Knowledge). This study examines the effectiveness of RFDT (Reading, Finding, Discussing, and Talking) learning grounded in TPACK to enhance students' critical and creative thinking. Using a one-group pretest-posttest pre-experimental design, 30 biology education students in professional education courses were assessed through critical and creative thinking essay tests administered before and after TPACK-based RFDT learning. Findings reveal a significant improvement in both critical thinking scores (from 62.3 to 77.63) and creative thinking scores (from 61.8 to 80.76), with $p < 0.05$. These results highlight the potential of TPACK-based RFDT in developing essential thinking skills, promoting a dynamic and interactive learning environment. Future research with a larger sample and advanced experimental designs is recommended to validate these findings further.

Abstrak. *Penekanan pada keterampilan abad ke-21, terutama berpikir kritis dan kreatif, telah mendorong kemajuan pendidikan, termasuk integrasi teknologi melalui kerangka TPACK (Technological Pedagogical Content Knowledge). Studi ini meneliti efektivitas pembelajaran RFDT (Reading, Finding, Discussing, and Talking) berbasis TPACK dalam meningkatkan kemampuan berpikir kritis dan kreatif siswa. Dengan menggunakan desain pra-eksperimen pretest-posttest satu kelompok, 30 mahasiswa program studi pendidikan biologi yang mengikuti mata kuliah profesi kpendidikan dinilai melalui tes esai berpikir kritis dan kreatif yang diberikan sebelum dan sesudah pembelajaran RFDT berbasis TPACK. Hasilnya menunjukkan peningkatan signifikan pada skor berpikir kritis (dari 62,3 menjadi 77,63) dan skor berpikir kreatif (dari 61,8 menjadi 80,76), dengan $p < 0,05$. Hasil ini menunjukkan potensi RFDT berbasis TPACK dalam mengembangkan keterampilan berpikir yang esensial, serta mendorong lingkungan belajar yang dinamis dan interaktif. Penelitian selanjutnya dengan sampel yang lebih besar dan desain eksperimental yang lebih kompleks direkomendasikan untuk memperkuat temuan ini.*

A. Introduction

Advances in information and communication technology have brought significant changes to the world of education. In this digital era, critical and creative thinking skills are competencies that are very necessary for students to face global challenges. These two abilities are not only important in academic contexts, but also in professional and personal life (Akpur, 2020; Hart et al., 2021). Therefore, educational institutions are required to develop effective learning methods in improving students' critical and creative thinking abilities. One lesson that is starting to get attention is Reading, Finding, Discussing, and Talking (RFDT) learning. The RFDT model is a learning model designed to increase student engagement and understanding through four main steps: reading, discovering, discussing, and speaking. This approach not only encourages creativity, but also improves analytical and problem-solving skills (Siswati & Suratno, 2024). This learning model also supports Higher Education Main Performance Indicator 7, namely collaborative and participatory classes.

However, the application of RFDT has yet to be widely researched, especially in terms of integrating it with an appropriate framework to optimize its impact. Several studies highlight the potential of the RFDT model in improving engagement and comprehension, yet research on its implementation within the TPACK framework remains limited. Integrating RFDT with TPACK offers an innovative solution, as TPACK (Technological Pedagogical Content Knowledge) helps structure learning that combines technology with effective pedagogy and relevant content (Brantley-Dias & Ertmer, 2013; Pamuk et al., 2015).

TPACK helps lecturers in designing and implementing learning that makes optimal use of technology, with appropriate pedagogical methods and relevant content (Rosenberg & Koehler, 2015). This integration is essential, as RFDT learning can greatly benefit from technological support to facilitate each stage—such as using online resources for "reading," interactive tools for "discovering," collaborative platforms for "discussing," and presentation tools for "talking." Thus, TPACK-based RFDT learning is expected to increase the effectiveness of the teaching and learning process and have a positive impact on students' critical and creative thinking abilities.

Students' critical thinking skills are very important to research because students, especially those studying in the field of education, are potential future educators. Critical thinking skills allow them to analyze information carefully, make informed decisions, and solve problems effectively (Bugg, 1997). This is a much-needed skill in education to face challenges in the learning process and help students achieve deeper understanding. As prospective educators, students who have critical thinking skills will be better able to develop innovative and adaptive learning methods, which can improve the quality of education (Silva et al., 2022; Thornhill-Miller et al., 2023).

In addition, critical thinking skills also help prospective educators evaluate and adapt curriculum and teaching strategies to better suit the needs of diverse students (Polat & Aydın, 2020). With these abilities, they can be effective agents of change in the education system, ensuring that they can guide students to become critical thinkers as well. Considering the important role of educators in shaping future generations, research on students' critical thinking skills is essential to ensure that they are ready to face the complex and dynamic demands of the teaching profession (Supena et al., 2021; Thorndahl & Stentoft, 2020). The ability to think creatively is very important because it encourages innovation and flexibility in problem solving. In a world that is constantly evolving and full of complex challenges, creative thinking allows individuals to produce new and effective solutions that do not rely solely on conventional approaches. Students who develop creative thinking skills are able to view problems from multiple perspectives (Suchyadi et al., 2020), design unique approaches, and adapt their strategies according to changing situations. This is especially important in a professional context, where the ability to adapt and innovate is key to success (Forte-Celaya et al., 2021; Yildiz & Yildiz, 2021).

Apart from that, creative thinking skills are important in improving the quality of learning and teaching, especially for prospective educators (Maskur et al., 2020). Creative educators can design learning activities that are more interesting and varied, so that students are more motivated and involved in the learning process (Ernawati et al., 2018; Simanjuntak et al., 2021). They are also able to integrate new technology and teaching methods that can improve students' understanding and skills. By developing creative thinking skills, prospective educators can create a dynamic and enjoyable learning environment, which will ultimately encourage students to also develop their creative abilities (Henriksen et al., 2020; Sirajudin et al., 2021). This is important to prepare students to face a future full of new challenges and opportunities.

This research aims to bridge the gap by evaluating the effectiveness of RFDT learning based on the TPACK framework in improving students' critical and creative thinking abilities. Through a pre-experimental method with a one-group pretest-posttest design, this research will measure changes in students' abilities before and after participating in TPACK-based RFDT learning. It is hoped that the results of this research can provide an important contribution to the development of innovative and

effective learning models in the digital era, as well as provide an empirical basis for the implementation of TPACK in the context of higher education.

B. Material and method

This research uses a pre-experimental method with a one-group pretest-posttest design to evaluate the effectiveness of RFDT (Reading, Finding, Discussing, and Talking) learning based on the TPACK (Technological Pedagogical Content Knowledge) framework in improving students' critical and creative thinking abilities.

The population of this study includes all students enrolled in the biology education study program at the University of Jember. From this population, a sample of 30 students was randomly selected, ensuring representation across various academic backgrounds. Random sampling was chosen to avoid selection bias and to ensure that the sample represents the broader student population within the program, increasing the generalizability of the study findings. This time allocation ensures that the research can be completed within one semester, covering the preparation, intervention, evaluation, analysis, and reporting phases.

This research design uses a one-group pretest-posttest, which involves measuring students' critical and creative thinking abilities before (pretest) and after (posttest) the TPACK-based RFDT learning intervention. This design aims to see changes that occur in the dependent variable as a result of the intervention provided. The procedure of this research include:

1) The pretest was carried out before the intervention, students were given an essay test to measure their critical and creative thinking abilities. This test consists of a series of questions designed to evaluate critical and creative thinking abilities according to each indicator (one week in week 1).
2) Intervention: Students take part in TPACK-based RFDT learning. This learning includes sessions designed to holistically integrate technology, pedagogy, and content packaged in the RFDT learning model. Students are invited to identify problems, conduct discussions, and design solutions through a critical thinking process (12 week in weeks 2 to 13).
3) Posttest: After the intervention, students are given the same test again to measure changes in their critical and creative thinking abilities (one week in week 14).

The test instrument in this research integrates both critical and creative thinking indicators into a single assessment. Critical Thinking is measured through indicators of interpretation, analysis, evaluation, and inference, while Creative Thinking is assessed through fluency, flexibility, originality, elaboration, and evaluation skills. Each question in the test was crafted to capture both dimensions, ensuring a comprehensive evaluation of both critical and creative thinking abilities.

To ensure the content and construct validity of the test instrument, a preliminary trial was conducted on a small sample outside the primary research subjects. The content validity was verified by consulting with experts who reviewed each question for relevance and alignment with the indicators, confirming that all questions were valid. Additionally, construct validity was assessed through an item analysis, which ensured that each question effectively measured the intended constructs of critical and creative thinking.

The reliability test was carried out by calculating the reliability coefficient using the Cronbach Alpha method. The Cronbach Alpha value of the questions used was 0.846, which indicates high reliability of the questions. Data obtained from the pretest and posttest were analyzed using the t test for paired samples (paired sample t-test). This analysis aims to see whether there is a significant difference between pretest and posttest scores, which indicates the effectiveness of TPACK-based RFDT learning.

To ensure the validity and reliability of the test instrument, a trial of the instrument was carried out first on a small sample outside the research subjects. The validity test was carried out using the content validity method through expert assessment (all questions used were valid), while the reliability test was carried out by calculating the reliability coefficient using the Alpha Cronbach method. The Cronbach Alpha value of the questions used was 0.846, which indicates high reliability of the questions.

C. Results and discussion

This research involved 30 students who took part in RFDT learning based on the TPACK framework in professional education courses. Data was obtained through pretest and posttest which measured students' critical and creative thinking abilities. Table 1 show a statistical description of the pretest and posttest results. Inferential analysis was conducted to test the research hypothesis, a paired sample t-test was carried out to compare pretest and posttest scores on critical and creative thinking abilities.

Table 1 The result of descriptive statistics

Ability	Pretest (Mean ± SD)	Posttest (Mean ± SD)
Critical thinking	62.30 ± 9.37	77.63 ± 6.31
Creative thinking	61.80 ± 8.05	80.76 ± 5.71

Critical Thinking Ability

The average difference between the pretest and posttest for critical thinking is -15.33 with a standard deviation of 11.54 can be seen in Table 2. The t value

is -7.28 with a df of 29, and the p value (Sig. 2-tailed) is .000. This indicates that RFDT learning based on the TPACK framework significantly improves students' critical thinking abilities. Table 3 presents the relationship between the RFDT learning model syntax and the indicators of critical thinking.

Table 2 Statistical test results of paired samples test of critical thinking abilities

Paired samples test								
	Paired differences					t	df	Sig. (2-tailed)
	Mean	Std. deviation	Std. error mean	95% confidence interval of the difference				
				Lower	Upper			
XCritical - YCritical	-15.33	11.53	2.10	-19.64	-11.02	-7.28	29	,000

Table 3 Relationship between RFDT learning model syntax and critical thinking indicators

RFDT components	Critical thinking indicators	Linkages
Reading	Interpretation	Reading academic material helps students interpret information, understand concepts and the context of the texts they read.
	Analysis	Through the reading process, students can analyze arguments, text structures, and relationships between ideas presented in the reading.
	Evaluation	Students learn to evaluate the credibility of information sources and the validity of arguments contained in the literature they read.
	Inference	Reading helps students make inferences or conclusions based on information interpreted from the text.
Finding	Interpretation	The process of finding information through reading carried out in the previous stage allows students to find patterns or themes in their search results.
	Analysis	Students are involved in analyzing the data collected, dissecting information, and understanding the structure of the data found.
	Evaluation	In finding information, students evaluate the quality and relevance of the data and sources used to ensure their validity and usefulness.
	Inference	Students draw conclusions and develop hypotheses based on analysis of data found during this finding stage.
Discussing	Interpretation	Discussions with classmates and lecturers help students interpret different ideas and clarify their understanding of the topics discussed.
	Analysis	Through discussion, students analyze different arguments and perspectives, breaking down complex ideas into easier-to-understand parts.
	Evaluation	Discussion allows students to evaluate the strengths and weaknesses of the arguments or solutions proposed by their peers.
	Inference	Students make inferences based on the points generated from the discussion, connecting various ideas to reach a logical conclusion.
Talking	Interpretation	Speaking and presentations help students interpret information by explaining and conveying the material back to the audience.
	Analysis	Students analyze feedback from the audience and critique questions or arguments that arise during the presentation to deepen their understanding.
	Evaluation	Presentations allow students to evaluate the effectiveness of their communication and the relevance of the information conveyed through audience responses.
	Inference	Through the speaking process, students can make new inferences and conclusions based on interactions and discussions that occur during presentations or question and answer sessions.

Enhancing the critical thinking skills of biology education students enrolled in professional education courses is closely related to the learning process they engage in. The RFDT (Reading, Finding, Discussing, Talking) learning model has shown effectiveness by structuring activities that actively involve students in developing their analytical abilities. The first stage, reading, is fundamental for building knowledge that forms the foundation of critical thinking. As Arisoy and Aybek (2021) and Ismail et al. (2022) have noted, reading comprehension enables students to construct a deeper understanding of texts, which strengthens their analytical framework.

The next stage, finding, emphasizes independent information-seeking, a process crucial for honing skills in identifying core ideas and structuring knowledge. This stage has been found to be instrumental in fostering students' critical

thinking, as it not only teaches them to extract relevant information but also develops their ability to discern and prioritize information based on context (Arisoy & Aybek, 2021). Comparatively, Fitriani et al. (2020) emphasized that encouraging students to engage in information searching independently is associated with improvements in problem-solving abilities, supporting the view that the RFDT's structured approach to critical thinking aligns with proven strategies in active learning.

Following this, the discussing stage allows students to share and refine their ideas collaboratively. The discussions foster critical thinking as students encounter and evaluate diverse perspectives (Henriksen et al., 2020). Reynders et al. (2020) similarly observed that structured group discussions help students build on their understanding by engaging with peer insights, while Henriksen et al. (2020) noted that the inclusion of discussion significantly benefits students' cognitive engagement and critical thinking skills in STEM fields. The effectiveness of the RFDT approach is further reinforced here, as students are not only learning from others but also developing evaluation and reasoning skills essential to critical thinking.

Finally, the talking (or speaking) phase of RFDT provides students with the opportunity to express their understanding verbally, which strengthens their argumentation skills and helps them internalize the material (Sari et al., 2021). The process of articulating thoughts aloud has been shown by Miterianifa et al. (2021) to aid in restructuring knowledge, which aligns with our findings that students benefit from the reorganization of information during verbal expression. This combination of reading, searching, discussing, and speaking sets the RFDT model apart from other approaches by actively engaging students across multiple stages of cognitive development.

Creative Thinking Ability

The t test results for creative thinking abilities also showed a significant difference between pretest and posttest scores ($t(29) = -11.776$, $p < 0.05$). This shows that there is a significant increase in students' creative thinking abilities after participating in TPACK-based RFDT learning. For more clarity, the results of the analysis can be seen in Table 4.

The RFDT learning model not only enhances students' critical thinking skills but also positively impacts their creative thinking abilities, particularly in the context of biology education. Each stage of the RFDT model aligns with the necessary components for fostering creativity. The initial reading stage (Reading) helps students comprehend relevant biological information, providing a strong knowledge foundation crucial for creative thinking. Exposure to diverse biological concepts during reading can inspire imaginative and creative responses.

The subsequent stage, Finding, prompts students to search for additional information, encouraging them to make connections between different biological concepts and expand their understanding of specific topics. This exploration fosters divergent thinking and allows students to consider multiple approaches and solutions (Gafour & Gafour, 2020; van Laar et al., 2020).

Table 4 Statistical test results of paired samples test of creative thinking ability

Paired samples test								
	Paired differences					t	df	Sig. (2-tailed)
	Mean	Std. deviation	Std. error mean	95% confidence interval of the difference				
				Lower	Upper			
XCreative - YCreative	-18.96	8.82	1.61	-22.26	-15.67	-11.77	29	,000

The third stage, Discussing, encourages students to engage in dialogues that allow for the exchange of ideas and the exploration of various perspectives regarding biological problems (Sirajudin et al., 2021). Such discussions create a collaborative environment that stimulates creativity through social interaction and idea exploration (Thornhill-Miller et al., 2023). In the final stage, Speaking (Talking), students articulate their creative ideas orally, developing necessary communication skills to express their thoughts clearly and persuasively. This stage also aids in reformulating and evaluating their ideas' quality (Lodge et al., 2018; Yayuk et al., 2020).

The effectiveness of the RFDT learning model in enhancing students' creative thinking skills lies in its comprehensive approach that supports the creative process from inception to evaluation. Through the stages of reading, finding, discussing, and speaking, students are empowered to explore ideas, innovate new solutions, and critically assess their work. This model not only encourages divergent thinking but also nurtures the development of flexible, original, and profound creative abilities in the context of biology education. The following table presents the relationship between the RFDT learning model syntax and the indicators of creative thinking (as presented in Table 5).

Table 5 Correlation between RFDT learning model syntax and creative thinking indicators

RFDT components	Creative thinking indicators	Linkages
Reading	Fluency	Reading various sources of information helps students generate many ideas and solutions based on various perspectives obtained from literature.
	Flexibility	Reading various types of material (articles, books, journals) encourages students to see problems from various points of view and develops flexibility of thinking.
	Originality	Being exposed to new and innovative ideas in literature helps students develop unique and original thinking.
	Elaboration	Reading allows students to deepen their understanding and detail ideas to form more complex and detailed concepts.
	Evaluation	Reading critical literature teaches students to evaluate information and ideas based on evidence and strong arguments.
Finding	Fluency	Finding information through reading activities allows students to produce various ideas and solutions based on the information collected.
	Flexibility	The finding process teaches students to adapt different approaches and develops flexibility in finding solutions.
	Originality	Conducting searches encourages students to ask new questions and develop original solutions based on their findings.
	Elaboration	Finding helps students detail their initial ideas with supporting data and in-depth analysis, strengthening their arguments.
	Evaluation	Through finding activities, students learn to evaluate the information they get to ensure their understanding
Discussing	Fluency	Group discussions encourage students to come up with many ideas and solutions in a short period of time, improving their fluent thinking skills.
	Flexibility	Discussions allow students to consider multiple perspectives and develop flexible and adaptive solutions.
	Originality	Interaction with others in discussions triggers new and original ideas that may not have occurred in an individual's thinking.
	Elaboration	Discussions help students expand and detail their ideas through feedback and suggestions from peers and lecturers.
	Evaluation	Discussion allows students to evaluate their own and others' ideas based on constructive criticism and argumentation provided in the group.
Talking	Fluency	Speaking and presentations allow students to express many ideas smoothly and without obstacles, practicing fluent thinking skills.
	Flexibility	During presentations, students must respond quickly to questions and unexpected situations, increasing their thinking flexibility.
	Originality	Presentations and public speaking provide opportunities for students to express their original ideas and receive immediate feedback.
	Elaboration	Speaking helps students elaborate on their ideas by explaining and detailing arguments and solutions in front of an audience.
	Evaluation	During presentations, students can evaluate the effectiveness of communication and the validity of their ideas based on responses and feedback from the audience.

To support this explanation with references from up-to-date international journals, several studies emphasize how the TPACK framework effectively enhances learning outcomes through technology integration, fostering critical and creative thinking in students. For example, a study by Koh et al. (2017) highlights that TPACK allows educators to blend content knowledge with appropriate technological tools, which significantly improves engagement and deeper learning processes, aligning with the goals of RFDT learning. Another study by Harris and Hofer (2020) discusses how the TPACK framework's flexibility in integrating pedagogy and technology supports innovative instructional strategies that lead to increased student engagement and critical thinking abilities.

Research by Rosenberg & Koehler (2015) further explains that the use of technology in education, when guided by TPACK, enables educators to design more interactive and collaborative experiences, directly supporting creative and critical thinking development. These studies align with the current findings, showing that RFDT-based TPACK learning can support dynamic, accessible, and impactful educational experiences..

D. Conclusions

This research demonstrates that RFDT learning based on the TPACK framework is effective in enhancing students' critical and creative thinking abilities, specifically within the context of biology education. These findings highlight the importance of applying

the TPACK framework in biology learning design to better prepare students for challenges in the digital era, such as understanding complex and applicable biological concepts. For future research, it is recommended to employ a more complex experimental design and involve a larger sample to strengthen the generalizability of these findings in the field of biology education.

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