An Investigation into Critical Thinking and Creative Thinking Skills for Science Pre-service Teacher in Fluid Mechanics Course

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Abstrak

Among the several skills required to be acquired in the 21st century, critical thinking (CTS) and creative thinking skills (CrTS) have significant importance for science pre-service teacher (SPST) to be instructed in during fluid mechanics. However, this study investigates the development of CTS and CrTS among SPST enrolled in fluid mechanics. It employs a descriptive quantitative research method. The study includes a sample of 46 SPST who were assessed using a test featuring questions designed to measure CTS and CrTS. The CTS test consisted of 5 essay questions covering various indicators, while the CTS test included 4 essay questions. The findings reveal that the CTS of SPST, particularly in areas such as reasoning and hypothesis testing, fall within the fair category. However, their skills in likelihood and uncertainty analysis, as well as argument analysis, are categorized as poor. Additionally, their abilities in problem-solving and decision-making indicators are assessed as very poor. Furthermore, the CrTS of these prospective teachers are categorized as very poor across all indicators.

Keywords: Critical Thinking Skill, Creative Thinking Skill, Fluid Mechanics Course.

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INTRODUCTION

In the beginning 1997, the words "21st Century Skills" have become part of the lexicon in education. Almost two decades, researchers were tasked with forecasting the potential difficulties that could emerge in the 21st century and identifying the learning strategies that could effectively address them (Kennedy & Sundberg, 2020). However, as we enter the 21st century, numerous publications emphasize the necessity of acquiring 21st-century skills in order to adequately equip students for success in a rapidly evolving world (González-Salamanca, Agudelo, & Salinas 2020), in an increasingly competitive global market (Kennedy & Sundberg, 2020) and upon thereafter joining the workforce (Ma, 2021; Gonzalez-Perez & Ramirez-Montoya, 2022; Thornhill-Miller, et.al., 2023; Kusmaryono & Nizaruddin, 2023). The changes in the world today are the rapid development of the digital, sustainable, and social world in an ethical and humanistic manner which necessitate the acquisition of 21st century skills (Gonzalez-Perez & Ramirez-Montoya, 2022).

The word "21st Century Skills" actually "soft skills" known as the "4Cs" (creativity, critical thinking, communication, and collaboration), more particularly (Thornhill-Miller, et.al., 2023). The Partnership for 21st Century Skills outlined a framework aimed at cultivating essential skills for success in both the modern workplace and society. This framework categorizes competencies into three main types: (1) learning skills encompassing creativity, critical thinking, problem-solving, communication, and collaboration; (2) literacy skills including information literacy, media literacy, and ICT literacy; and (3) life skills such as flexibility, adaptability, initiative, self-direction, social and intercultural skills, productivity, accountability, leadership, and responsibility (The Partnership, 2019).

In today's context, certain competencies have gained significant importance. These include (1) the ability to reason through complexity, involving systems thinking and critical thinking skill (CTS); (2) scientific reasoning; (3) creative thinking skill (CrTS); and (4) scientific thinking, aimed at innovating new solutions to address societal needs (Tecnologico de Monterrey, 2019).In Indonesia, the 21st century learning began in 2013 in the 2013 Curriculum which was revised in 2017 (Diniya, 2019). The curriculum has stated that the important 21st century skills to be taught are CTS, CrTS innovative and problem-solving skills. Critical thinking is an important goal of higher education to form critical thinkers to make decisions and take appropriate actions (Ma, 2021; Kusmaryono & Nizaruddin, 2023). There are two inseparable components that are developed in parallel, CTS and CrTS. There is a need for integration and reciprocity between the two during the teaching process because critical thinking without creativity will only result in what is referred to as skepticism and creativity without critical thinking will only result in originality. Thus, critical thinking and creative thinking are important skills that science pre-service teacher (SPST) must have to face the challenges and problems in the 21st century.

Not only at the school level, critical thinking skills must also be taught in universities in the 21st century (Akpur, 2020). A survey of 167 science graduates compared the development of various skills at university with skills used in the workplace. The survey revealed that 30% of graduates identified CTS as one of the top five skills they aimed to enhance during their undergraduate studies (Sarkar, et al., 2016). There exists a notable disparity between skills acquired in educational settings and those demanded for effective performance in professional and societal contexts (González-Salamanca, Agudelo, & Salinas 2020). Indeed, 21st century frameworks propose strategies for identifying the essential skills students need to prepare for the future workforce. Consequently, educators face the responsibility of evaluating whether current competencies and teaching approaches are adequately designed to achieve these goals (Gonzalez-Perez & Ramirez-Montoya, 2022).

Research conducted by (Kocak et al., 2021) shows that there is a direct influence between CrTS, algorithmic thinking, cooperative, and digital literacy on CTS and indirectly contribute to problem solving skills. The importance of nurturing creative and algorithmic thinking skills for enhancing CTS cannot be overstated. These skills play a crucial role in advancing problem-solving abilities and critical thinking. Noh et al. (2021) emphasized that educators should adopt a design-thinking mindset to cultivate students' creativity and innovation skills in the context of Education 4.0.

This approach includes techniques such as user-focused design, understanding others' perspectives, working together, maintaining positivity, trying new ideas, creating initial models, and being mindful of the process. Additional studies by Venegas et al. (2021) propose broadening educational methodologies beyond conventional classroom practices to integrate computational thinking through educational robotics and programming within the context of Education 4.0.

Additionally, van Laar (2017) introduced a model that combines fundamental skills. These encompass primary skills such as managing information, communicating effectively, collaborating, fostering creativity, understanding technology, and solving problems. This is supplemented by situational skills such as ethical sensitivity, cultural sensitivity, adaptability, self-management, and continuous learning. The aim of this model is to guarantee that educational programs foster a comprehensive array of skills—foundational, situational, and digital.—within integrated educational frameworks. The findings of a study conducted by Liuta, et. al (2019) on learning strategies employed in the context of fluids indicate that instructors can enhance the educational effectiveness of students while teaching new subjects by employing straightforward explanations and providing analogies. However, the level of interest in the questions can be increased by presenting them in the format of crossword puzzles and, in certain instances, allowing students to assess their own level of preparedness in learning. The utilization of uncomplicated explanations and illustrative instances during the examination of intricate mechanical systems is highly significant and remarkably efficient. As an illustration, the human heart functions as a pump, while the blood serves as a working fluid. The blood arteries can be likened to hydraulic systems, while the hands and feet act as propulsive motors. This simple analogy can assist pupils who are struggling.

The research undertaken by Wijaya, et. al. (2021) demonstrates that utilizing dynamic mathematical software to pick and merge information with art can promote communication abilities, problem-solving skills, creative thinking, and self-confidence among prospective teachers. The research conducted by Pérez-Sánchez & López-Jiménez (2020) illustrates that continuous project-based learning (PjBL) in fluid mechanics and hydraulic engineering courses leads to favorable outcomes in terms of sustainability. Additional studies have also discovered that Critical Thinking Activities (CTAs) can improve critical thinking abilities by implementing activities related to the subject of Fluid. Applying problem-solving methods in real-world scenarios, connecting theoretical ideas to everyday situations, and encouraging critical thinking can enhance learning results. The citation (Cossu, Awidi, & Nagy, 2024) is provided. Prior studies conducted by Kurniawan, Sanusi, and Kharimah (2017) have demonstrated that utilizing virtual simulations to teach static fluid concepts to aspiring mathematics teachers can greatly enhance their critical thinking abilities. The findings of Jauhariyah's (2017) study on fluids in the Analysis of Physics Curriculum II course, using Problem Based Learning, indicate a significant improvement in learning outcomes. Zahara, Yusrizal & Rahwanto (2018) did research on the idea of fluid in the Basic Physics course. They used multimedia based on PhET simulation and found that it led to a significant improvement in students' CTS.

Departing from this fact, efforts to improve the quality of critical thinking and creative thinking of SPST must be continuously carried out, among others through lectures. CTS will be impacted through integrated courses (Zhang et al., 2022). Creative thinking skills can be trained through teaching (Torrance, 1973). It is very important to prepare students for their role as future teachers in post-education and in society (Uçar & Demiraslan Çevik, 2020). In line with what Willingham (2019) wrote that planning how to teach students to think critically is one of the tasks of a teacher. Learning to think critically is likened to learning a language as a baby. Babies will more easily learn a language when their environment uses the language. Therefore, it is also important for students who will become teachers to have the ability to think critically and creative thinking skill so that they can carry out higher quality learning as well as provide provision for students to improve critical an creative thinking skills

Thus, before implementing learning innovations, it is important for teachers to know in advance the initial level of CTS and CrTS of SPST. The purpose of this study is to examine in depth related to the of CTS and CrTS of SPST before studying the fluid mechanic course.

METHOD

This study employs a quantitative descriptive approach, specifically using survey research methods. Its objective is to investigate the development of CTS and CrTS within the context of the Fluid Mechanics course. The research time was carried out in the even semester of the 2023-2024 academic year. The research location is in one of the state universities in Pekanbaru City, Riau Province, Indonesia. The population of this study were all science pre-service teacher in the 2023-2024 academic year. The sample is science pre-service teacher who have contracted the Fluid Mechanics course. The number of samples was 46 science pre-service teachers.

The research utilized a test instrument comprising five essay questions designed to assess indicators of critical thinking skills as specified by Tiruneh, De Cock, & Elen (2017), namely reasoning (R), thinking as hypothesis testing (HT), likelihood and uncertainty analysis (LUA), argument analysis (AA), problem solving and decision making (PS-DM).

Table 1. Description of Domain Specific Critical Thinking Skill Outcomes.

CTS Indicator	**Domain Specific CTS Outcomes**
	In the context of Fluid Mechanics, SPST will be able to:
R	Analyze the findings of the experiment.
HT	Approach thinking as testing hypotheses.
LUA	Deduce accurate statements from a provided dataset.
AA	Recognize the necessity of acquiring further information when making decisions.
PS-DM	• Make valid predictions • Make sound, evidence-based decision

The data collected was then analyzed descriptively to reveal science pre-service teachers' critical thinking skills. Data analysis was carried out in general which included all indicators and analyzed in detail on each indicator. Data categorization is guided by the critical thinking skills expressed by Rahmawati et al. (2019), namely the categories of very good, good, fair, less, and very less.

Table 2. Category of Science Pre-Service Teachers Critical Thinking Skill Score

No	Percentage	Category
1	81-100	Very good
2	61-80	Good
3	41-60	Fair
4	21-40	Poor
5	0-20	Very poor

Creative thinking questions as many as four essay questions containing indicators of creative thinking according to Torrance (1985) consisting of fluency, abstractness of titles, elaboration and originality.

Table 3. Description of Desired Domain Specific Creative Thinking Skill Outcomes

Creative Thinking Skill	**Domain Specific Outcome**
In the context of fluid mechanics, the preservic teacher will be able to:	
Fluency (F)	- The quantity of pertinent concepts - Proficiency in generating a variety of visual representations
Originality (O)	Generation of uncommon or distinctive responses
Elaboration (E)	- The quantity of supplementary ideas - Demonstrates the subject's capability to expand and elaborate on ideas
Abstractness of titles (AT)	The extent to which the concept goes beyond mere labeling is based on the notion that creativity necessitates abstract thinking.

The data collected was then analyzed descriptively to reveal science pre-service teachers' creative thinking skills. Data analysis was carried out in general which included all indicators and analyzed in detail on each indicator. Data categorization is guided by the creative thinking skills expressed by Riduwan (2012) namely the categories of very good, good, fair, poor and very poor.

Table 4. Category of Science Pre-Service Teachers Creative Thinking Skill Score

No	Percentage	Category
1	81-100	Very good
2	61-80	Good
3	41-60	Fair
4	21-40	Poor
5	0-20	Very poor

RESULTS AND DISCUSSION

In this section, researchers will display some of the results in the form of descriptive statistics related to the CTS and CrTS of science pre-service teachers. The results of the analysis will be displayed for each related indicator.

Table 5. Summary Table of Descriptive Statistic for Critical Thinking Skills of SPST

	Variable				
Statistic	**R**	**HT**	**LUA**	**AA**	**PS-DM**
Sample	46	46	46	46	46
Mean	9,67	9.24	4,24	5,76	3,04
Standard Deviation	5,65	5,89	4,17	6,25	3,97
Variance	32,67	35,52	17,74	39,96	16,09

Based on Table 5, the highest mean score is obtained for reasoning indicator which is 9,67. Followed by the mean score of thinking as hypothesis testing indicator which is 9,24. The argument analysis indicator, which is 5.76. The uncertainty analysis indicator has a mean score of 4.24. The lowest mean score is problem-solving and decision-making indicator which is only 3,04.

Table 6. Critical Thinking Skill Category for Science Pre-service teacher

Indicator	Mean Score	Percentage (%)	Category
R	9,67	48,37	Fair
HT	9,24	46,20	Fair
LUA	4,24	21,20	Poor
AA	5,76	28,80	Poor
PS-DM	3,04	15,21	Very poor

The SPST's CTS average percentage can be seen in the following figure 1.

According to Figure 1, it is evident that the CTS of science pre-service teachers fall into the fair category for reasoning and thinking as hypothesis testing indicators. However, indicators such as Likelihood and Uncertainty analysis and argument analysis are rated in the poor category, and Problem-solving and Decision-making indicators are in the very poor category. These results stem from the data analysis conducted on the CrTS of science pre-service teachers.

In the reasoning indicator, science pre-service teachers' CTS are categorized as fair. This is related to the argument analysis indicator which has a very poor category. Reasoning and argument analysis have a reciprocal relationship so that if science pre-service teachers have good argument quality, then their reasoning skills are also good, and vice versa. In accordance with the results of the study which states that science pre-service teachers who show high argumentation quality, are more adept at carrying out the scientific reasoning process and show greater frequency in conducting self-monitoring during tasks. Integrating teaching with self-regulation and scientific reasoning can improve scientific argumentation skills (Omarchevska, Y., et. al., 2022).

Furthermore, indicators related to thinking as hypothesis testing also fall within the fair category. Hypothesis formulation constitutes a crucial scientific process skill aimed at articulating assumptions that define relationships between variables. It is feasible to generate various hypotheses for each phenomenon (Trúsiková & Velmovská, 2022).

When science pre-service teachers formulate hypotheses, they rely on critical thinking, which, according to The American

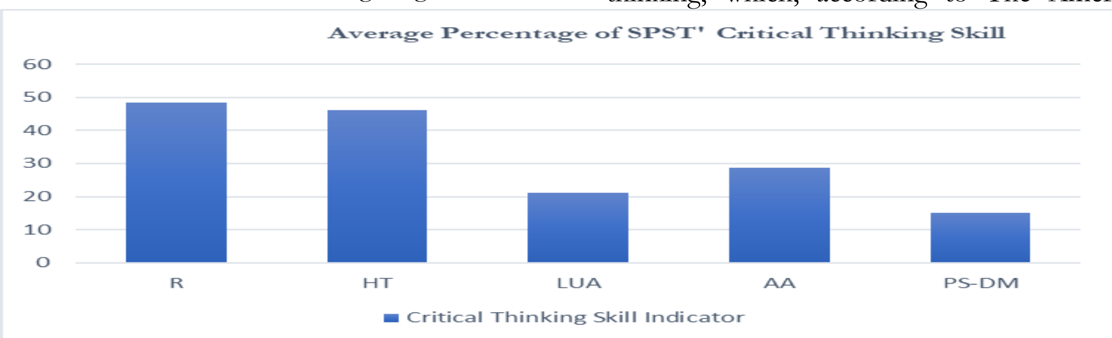

Figure 1. Average Percentage of SPST's Critical Thinking Skill

Philosophical Association, involves being well-informed and valuing reasoning. These attributes become especially significant when these teachers articulate justified assumptions. Moreover, science pre-service teachers may encounter scenarios where they propose multiple hypotheses for a given phenomenon or collaborate in groups where each member presents different hypotheses. In such situations, it is crucial for science pre-service teachers to demonstrate flexibility in considering alternatives and perspectives, as well as understanding the viewpoints of others (Trúsiková & Velmovská, 2022).

Table 7. Summary Table of Descriptive Statistic for Creative Thinking Skills of Science Pre-service Teacher

Statistic	Variable F	O	E	AT
Sample	46	46	46	46
Mean	9,60	8,70	8,15	9,06
Standard Deviation	4,24	4,58	4,42	3,39
Variance	18,41	21,47	20,02	11,80

Based on Table 7, it can be seen that the mean score on the fluency indicator is 9.60, then the Abstractness of title indicator is at a mean score of 9.06, while the originality indicator is at mean score of 8.70.

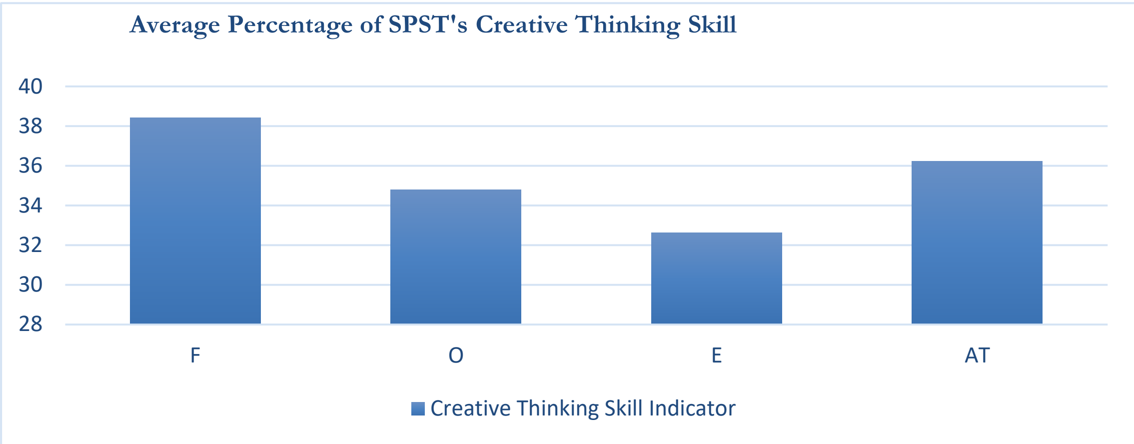

Figure 2. Average Percentage of SPST's CreativeThinking Skill

The elaboration indicator is at the lowest mean score of 8.15. Furthermore, Table 8 will show data on the category of creative thinking skills on each indicator.

Table 8. Creative Thinking Skill Category for Science Pre-service teacher

Indicator	Mean	Percentage (%)	Category
F	9,60	38,41	Poor
O	8,70	34,78	Poor
E	8,15	32,61	Poor
AT	9,06	36,23	Poor

Based on Table 8, it can be seen that each indicator is in the percentage range of 21-40 percent so that it can be categorized as poor. The SPST creative thinking skills average percentage can be seen in the following figure 2.

Cooperative skills, digital literacy, creativity, algorithmic thinking, and 21st century problem solving are all mediated by critical thinking (Kocak et al., 2021). Predicting the development of scientific pre-service teachers' creative thinking skills hinges significantly on their critical thinking abilities. According to Ülger (2016), critical and creative thinking involve a diverse set of qualities. Table 8 indicates that creative thinking indicators are considered inadequate when they fall within the 21-40 percent range. The interplay between critical and creative thinking is evident in problem-solving and decision-making indicators. Creative thinking often involves approaching issues from unconventional perspectives, which initially may seem disruptive. Both structured methods like heuristic programs and unstructured processes such as brainstorming can cultivate creative thinking (Gafour & Gafour, 2020).

According to Long & Long (2023), there

was a positive relationship found between students' critical thinking and creativity. Moreover, this positive relationship between creativity and CTS was largely influenced by the students' creative self-efficacy (CSE). Additionally, the connection between critical thinking, CSE, and creativity is positively influenced by perceived school support for creativity (PSSC). Higher levels of PSSC among students enhance the promoting effect of critical thinking on CSE, thereby fostering creativity. Poor creative thinking abilities among students also impact their comprehension of physics. Previous research (Fitriani et al., 2016) suggests that students struggle with grasping the material when they lack personal engagement with the subject matter, a finding supported by empirical data. According to Fatmawati (2016), it is essential for students to develop and nurture creative thinking skills to enhance their ability to solve novel problems creatively. Creative thinkers can generate innovative ideas and delve deeper into their areas of study. Afandi et al. (2019) suggests that students who lack 21st-century skills may experience uncertainty and confusion when faced with global challenges. Wang (2018) argues that educational reform is imperative because the educational system faces significant challenges in producing skilled students.

In addition, it was discovered that the lecturer had given out the lesson plan at the start of the session and described the lecture procedures that would be followed over the course of the following four months, according to the interview results. Lecturers use the University Physics book written by Giancoli and several other supporting sources. The lecture mentioned that there were no unit tests conducted, but instead, assignments were given either individually or in groups. Additionally, problem-solving exercises in the form of questions were integrated into the lessons. The midterm exam questions are structured according to Bloom's taxonomy. These questions are centered around real-life problems and are solved using formulas related to static fluids that have been covered in the course.

Furthermore, it was found that at the beginning of the session, the lecture provided the lesson plan and outlined the lecture procedures that would be followed over the next four months, as indicated by the interview findings. Technical reasoning tasks that pose greater complexity for students include solving equations with multiple variables, distinguishing between temporal and spatial changes, and understanding the implications of physics idealization (Schäfle, 2021). Therefore, continuous efforts, such as those in fluid mechanics, are needed to improve the critical thinking skills of prospective teachers' students.

Emphasizing knowledge transmission over fostering thinking skills poses challenges to the development of critical thinking. There is a need for deeper consideration on methods to enhance children's critical thinking abilities. According to Changwong et al. (2018), teachers are responsible for nurturing critical thinking skills in students from a young age. Teachers should strive to cultivate these skills using appropriate methodologies, as suggested by Agboeze et al. (2013).

Integrated training had a notable effect on critical thinking skills. Analyzing the thought process through practical scenarios relevant to the student's field and providing constructive feedback when applying critical thinking to problem-solving, while observing peers and teachers who demonstrate strong critical thinking, are essential elements of a well-designed course (Zhang, Tang & Xu, 2022). Therefore, educators play a pivotal role in creating optimal conditions and methods to foster the development of CTS and CrTS among SPST.

CONCLUSION

Critical thinking skills of science pre-service teacher in the reasoning and thinking as hypothesis testing indicators are in the fair category. For indicators of likelihood and uncertainty analysis and argument analysis are in the poor category while for indicators of problem-solving and decision makingare in the very poor category. Science pre-service teacher creative thinking skills are in the very poor category for each indicator.

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