

Measuring students' creative thinking skills with SCI-Fi (Science Creative Instrument in Fluids): How Suitable Is It?

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Abstract:

This study aims to develop an instrument capable of accurately and effectively assessing each indicator of students' creative thinking skills in physics. The instrument, called SCI-Fi (Science Creative Instrument in Fluids), was designed in essay with extended response format to stimulate and broaden students' imagination while completing the tasks. This study follows a research and development approach using the ADDIE model. To determine the suitability of the instrument in measuring creative thinking indicators, item validation was carried out using the Rasch model involving 95 respondents. The results show that SCI-Fi meets the criteria for both validity and reliability based on Rasch parameters. Therefore, it can be concluded that SCI-Fi is a suitable and appropriate tool for measuring students' creative thinking skills in physics. The findings of this study suggest that SCI-Fi holds significant potential as a diagnostic and evaluative tool for educators in identifying students' creative thinking profiles and designing targeted instructional interventions to foster these skills in science learning. Moreover, the instrument may serve as a valuable reference for curriculum developers and researchers seeking to assess or enhance creative thinking across a broader range of scientific domains and educational levels.

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Introduction

Binkley (2023) classify thinking skills into three core competencies: innovative and creative thinking, critical thinking for drawing conclusions, and managing metacognitive abilities. These three skills are essential for effective problem-solving. In today's digital era, individuals are increasingly required to demonstrate creativity and innovation in any field they pursue.

As one of the key 21st-century thinking skills, creative thinking has become a crucial competency to be developed (Asquith et al., 2022; Dashkina et al., 2022). However, in practice, people often experience anxiety when forced to think creatively. In psychology, this phenomenon is known as creative anxiety (Hsia et al., 2021; Zhong, 2022). Daker et al. (2020) explain that creative anxiety can significantly impact an individual's performance. To overcome this, individuals must be conditioned to regularly engage in creative thinking and foster positive self-suggestions.

The importance of creative thinking extends beyond educational settings, as it plays a central role in problem-solving, innovation, and adaptability, skills that are vital in the face of complex, real-world challenges (Dimitrakopoulou & Lewis, 2022; Krstić et al., 2020). In the context of science education, creative thinking enables students to generate novel hypotheses, approach problems from multiple perspectives, and design innovative solutions (Li, 2020; Saeed & Ramdane, 2022). Thus, fostering creative thinking is not merely an academic exercise but a foundational skill for preparing learners to thrive in dynamic, technology-driven environments (Forte-Celaya et al., 2021).

Developing creative thinking habits can be achieved through the learning process. As one of the four essential 21st-century skills, creative thinking is a competency that can be nurtured through education (Tabieh et al., 2020; Zhou, 2021). However, does every learning approach effectively foster creative thinking? Unfortunately, the answer is no. Creative thinking is best cultivated through effective learning strategies where students actively engage in constructing their own knowledge (Hsia et al., 2021; Larraz-Rabanos, 2021; Sari, 2020).

Numerous studies have identified various learning models that can foster or enhance creative thinking skills. Each year, research trends related to creative thinking continue to rise. An analysis of data from Scopus shows that between 2021 and 2024, the number of published articles on creative thinking has steadily increased. Figure 1 illustrates this upward trend.

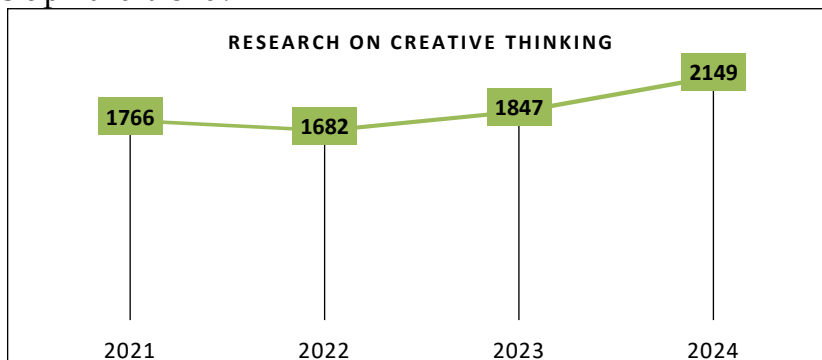


Figure 1. Publication trends of articles on creative thinking from 2021 to 2024

As of 2025, even though the year is not yet complete, a total of 354 articles related to creative thinking skills have already been published. This highlights the significant global attention given to the development of creative thinking, including within the field of education. Many educators and researchers from various countries have conducted studies on creative thinking, aiming to integrate and foster this skill in classroom settings. This has been done through the application of learning models, approaches, strategies, and instructional media, one of the most notable being the problem-based learning model (Aulia Rahman et al., 2020; Yaniawati et al., 2020), STEM approach (Ozkan & Umdu Topsakal, 2021; Pramesti et al., 2022; Sun et al., 2022), including the implementation of problem-based learning models, or even by simply utilizing technology as an instructional tool (Aldalalah, 2020; Atun & Latupeirisa, 2021; Park & Kim, 2021).

Several researchers have also reported positive findings regarding creative thinking enhancement through various instructional interventions. For instance, (Agustiana et al., 2021) found that the creative responsibility-based teaching model is effective in improving students' scientific creativity. Similarly, Saregar et al. (2020) reported that the implementation of the STEM approach has a positive impact on students' creative thinking skills. Other studies have shown that students' creative thinking can be enhanced through the application of problem-based learning models (Ernawati et al., 2023; Srikan et al., 2021; Widiastuti et al., 2023). Furthermore, Hamdani et al. (2022) demonstrated that creative thinking skills can also be improved by using Android-based multimedia learning. Many other studies have echoed similar findings, reinforcing the importance of well-designed learning interventions in fostering creativity.

Most prior studies emphasize learning interventions but overlook the need for valid and reliable assessment tools to monitor students' creative thinking growth over time. This study addresses this gap by developing and validating SCI-Fi (Science Creative Instrument in Fluids), an instrument specifically designed to measure students' creative thinking indicators in physics, especially in fluids topic, thus providing teachers with a means to track and evaluate students' creative thinking performance more systematically.

Based on the identified gaps in existing literature, this study aims to develop and validate an assessment instrument specifically designed to measure students' creative thinking skills in the context of physics, with a particular focus on the topic of fluids. The objectives of this research are to construct a theoretically grounded and empirically validated tool that captures the key indicators of creative thinking, to evaluate its psychometric properties through the Rasch model, and to assess its feasibility for implementation in actual classroom settings.

Measuring creative thinking skills is essential in the learning process, as education should not only focus on the transfer of information but also on monitoring students' progress in developing their thinking abilities. Therefore, this study presents the development of a creative thinking assessment instrument, supported by detailed item analysis using the Rasch Model. More specifically, this research seeks to explore what kind of instrument is appropriate for measuring students' creative thinking skills, how such an instrument can be systematically developed, the extent to which

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the instrument demonstrates validity and reliability, and whether it is feasible for practical use.

Research Method

Research Design

This study employs the ADDIE development model (Analyzing, Designing, Developing, Implementing, Evaluating), which, as the name suggests, consists of five stages of development (Srikongchan et al., 2021; Wibowo et al., 2020). The complete process of instrument development is presented in Figure 2.

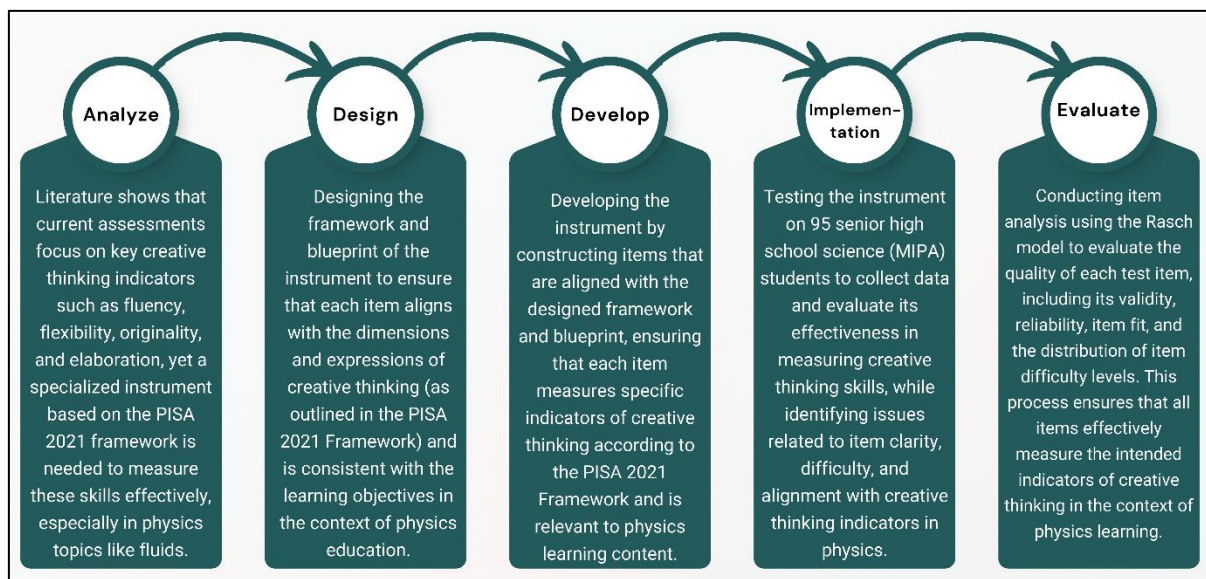


Figure 2. SCI-Fi Development Process

Respondent

A random sampling technique was used to collect data from 95 students in the science program from high schools in Lampung, Indonesia. Students' anonymity was guaranteed to protect their identity. The respondents were Grade 11 science students (aged 15-17 years), consisting of 53 females and 42 males. The participants were given 60 minutes to complete the SCI-Fi under teacher supervision in face-to-face or online classes.

OECD (PISA 2021) Framework for Creative Thinking Skills

Creative thinking is a student's ability to generate expressions or ideas that are unique, different from the norm, original, aesthetically pleasing, innovative, efficient, purposeful, and effective (Akpur, 2020). Referring to the creative thinking framework developed by OECD (2021), creative thinking is not limited to generating 'brilliant' and unique ideas, but also involves evaluating, developing, and refining ideas.

Recently, the Programme for International Student Assessment (PISA) introduced a new creative thinking framework that differs from Treffinger's model of creative thinking skills. The PISA 2021 creative thinking framework, as adapted for science learning, is presented in Figure 3.

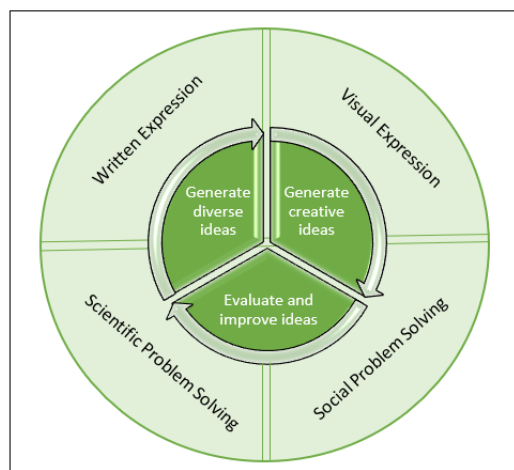


Figure 3. PISA 2021 Creative Thinking Framework

In the PISA creative thinking framework, the indicators go beyond the traditional categories of fluency, flexibility, originality, and elaboration. PISA defines creative thinking as a multidimensional process that involves generating, evaluating, and refining ideas with clear purpose and relevance. Specifically, the framework outlines three core cognitive processes: generating diverse ideas, generating creative ideas, and evaluating and improving ideas. Each of these processes is applied across various domains of expression, including written tasks, visual tasks, scientific problem solving, and social problem solving (for social sciences). This structure ensures that creative thinking is assessed not only through the quantity and originality of ideas but also through how well students refine and apply their ideas in meaningful and practical ways.

SCI-Fi (Science Creative Instrument in Fluids)

Assessment in learning is the process of collecting and analyzing information to measure students' progress in developing skills and competencies. Meanwhile, an instrument is a tool used to gather data (Elangovan & Sundaravel, 2021; Mazhar, 2021; Taherdoost, 2021). The type of instruments that sometimes used to assess creative thinking skills are the multiple choice and multi-tier test, which typically takes the form of multiple-choice questions with reasoning (Istiyono, 2020; Mursid et al., 2022). In this case, the 'reasoning' tier, which is presented in essay form, serves to assess thinking skills (Ndiung et al., 2021). Other studies have also found that essay tests are highly effective in identifying students' thinking abilities (Suherman & Vidákovich, 2022).

Another type of test that is also considered effective for measuring creative thinking skills is the extended response essay (Busyairi & Sinaga, 2021). In an extended response, students are given the freedom to imagine and propose their own solutions or opinions for a given problem. This type of test encourages students to think critically about the reasoning behind their answers, requiring them to work harder to justify the solutions they initially provide. Compared to standard multiple-choice questions, essay-based assessments are undoubtedly more effective in measuring thinking skills (Ndiung et al., 2021; Suherman & Vidákovich, 2022). In multiple-choice

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questions, students tend to rely on guessing. This comparison is further explained in Table 1.

Table 1. Comparison between multiple-choice questions and opinion-reason questions on the generate diverse ideas (written) indicator.

Multiple Choice	<p>Question: Karina placed an object with a density of 1.050 kg/m^3 on the surface of water in a container, but the object sinks. For a photography project, Karina needs to make the object float on a clear fluid like water. Choose what Karina could do to make the object float!</p> <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p>Answer choices:</p> <ol style="list-style-type: none"> a. Adding sugar b. Replacing the water with glycerin c. Boiling the water d. Replacing the water with oil e. Adding soap into the water </div>	<div style="border: 1px solid black; padding: 5px; text-align: center; margin-bottom: 10px;"> Generating diverse ideas to solve a problem </div> <p style="text-align: center;">↓</p> <p>If students are able to answer this question, it shows that they not only understand the concept but can also apply it to solve problems from a different perspective.</p> <p style="text-align: center;">↓</p> <div style="border: 1px solid black; padding: 5px; text-align: center;"> <p>However, the provided answer choices limit students' creativity and create opportunities for them to guess randomly.</p> </div>
Extended Response	<p>Question: Karina placed an object with a density of 1.050 kg/m^3 on the surface of water in a container, but it sank. For photography purposes, Karina needs to make the object float on a clear fluid like water. Write at least two possible ways Karina could make the object float and explain your reasoning!</p> <p>Answer:</p> <div style="border: 1px solid black; padding: 10px; margin-top: 10px; text-align: center;"> <p>Solution & Reason:</p> </div>	<div style="border: 1px solid black; padding: 5px; text-align: center; margin-bottom: 10px;"> Generating diverse ideas to solve a problem </div> <p style="text-align: center;">↓</p> <p>If students are able to answer this question, it shows that they not only understand the concept but can also apply it to solve problems from a different perspective.</p> <p style="text-align: center;">↓</p> <div style="border: 1px solid black; padding: 5px; text-align: center; margin-bottom: 10px;"> <p>Allowing students to answer as creatively as possible based on their understanding.</p> </div> <p style="text-align: center;">↓</p> <div style="border: 1px solid black; padding: 5px; text-align: center;"> <p>Requiring students to justify their opinions and helping them develop their thinking skills.</p> </div>

The PISA creative thinking framework has been adapted in the development of the SCI-Fi instrument to ensure that each indicator is clearly represented in the assessment items. This integration allows the instrument to assess creative thinking not only in terms of generating ideas but also in how students express, refine, and apply their ideas in scientific contexts. The adaptation process aligns with PISA's emphasis on measuring creative thinking across various expressions, such as written, visual, and scientific problem solving. The detailed application of this framework within the SCI-Fi instrument is presented in Table 2.

Table 2. Aspects of Creative Thinking and Item Distribution in SCI-Fi

Creative Domain Framework)	Thinking (PISA Ekspresi	Description	Item Number
Generate diverse ideas	Written	Given a case related to a sinking object, students provide various ideas and reasoning on how to make the object float.	6, 12
	Visual	Given data on hydrostatic pressure, students illustrate the processed data in the form of a drawing.	1, 11, 25
		Given data on the depth-related pressure of a solid, students illustrate the processed data in the form of a drawing.	4, 23, 24
Scientific	Given images of simple tools, students design three different experiments using the provided tools.	9, 13	
Generate creative ideas	Written	Given several components of hot air balloon technology, students create a storyline to operate the technology according to Archimedes' principle.	2, 21, 22
	Visual	Given a situation related to the phenomenon of buoyant force, students visualize the situation through a drawing.	5, 14
	Scientific	Given a design, students suggest improvements to the components based on the concept of viscosity.	10, 19, 20
Evaluate and improve ideas	Written	Given a problem related to Pascal's law, students propose an alternative solution that aligns more accurately with the application of Pascal's law.	8, 15, 16
	Visual	Given an image showing the height of fish in an aquarium, students identify and correct errors in the data based on the concept of hydrostatic pressure.	3, 18
	Scientific	Given a case involving hydrostatic pressure, students evaluate and correct the actions taken in the scenario.	7, 17

Data Analysis Technique

The item analysis in this study was conducted using the Rasch Model (Safira et al., 2020; Yuberti et al., 2024). The analysis covers descriptive statistics, reliability and validity testing, item-fit and person-fit statistics, and item difficulty levels (Item measure). The validity of both items and respondents is evaluated using the infit and outfit mean square (MNSQ) values, with an acceptable range of 0.5 to 1.5, although values up to 1.6 are still acceptable when supported by a positive point-measure correlation (PTM CORR). Ideally, the MNSQ should approximate 1.00 logits, which indicates a good model fit. For sample sizes below 250, ZSTD values between -2.0 and +2.0 are also accepted, though ZSTD and PTM CORR may be disregarded if MNSQ values meet the criteria. Construct validity is established through the unidimensionality test, which ensures that the instrument consistently measures a single construct while capturing a range of student abilities. The data is deemed unidimensional when the explained variance exceeds 20% and the unexplained variance in the first contrast is less than 15%. Although DIF analysis is often used to detect item bias across groups such as university type, gender, or semester, significant DIF is typically indicated by a p-value < 0.05 or a DIF contrast exceeding 1.00 logits. This study follows Rasch analysis procedures as outlined by Bond & Fox (2015) and Linacre (2022). Additionally, the Logit Value of Person (LVP) is applied to categorize students' creative thinking abilities into four levels based on the mean (M) and standard deviation (SD) of their logit scores.

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Results and Discussion

In this study, quantitative data is analyzed using the Rasch model to validate the SCI-Fi instrument and assess students' creative thinking skills. The analysis examines whether the data fits the Rasch model's requirements. The results are presented in the following section, focusing on validity and reliability as the main parameters. A summary of the statistical findings on students' creative thinking, based on the Rasch model output, is shown in Table 3.

Table 3. Summary statistics of person and items

Psychometrics attribute	Person	Item
Number (N)	95	25
Mean INFIT		
MNSQ	0.99	0.98
ZSTD	0.09	-0.23
Mean OUTFIT		
MNSQ	1.09	1.09
ZSTD	0.08	-0.12
Separation	6.76	11.76
Reliability	0.99	
Cronbach's Alpha	0.98	
Unidimensionality		
Raw Variance Explained by measures		82.5%
Unexplained Variance First Contrast		1.7%

Table 3 presents the reliability test results of the creative thinking skills instrument, showing a person reliability (Cronbach's Alpha) of 0.98 with a separation index of 6.76 (> 2), and an item reliability of 0.99 with a separation index of 11.76 (> 2). These values indicate an excellent level of reliability, confirming that all items consistently function in the same direction to measure students' creative thinking skills in the context of fluid mechanics (Fisher, 2020). Additionally, the raw variance explained by measures is reported at 82.5%, categorized as excellent since it exceeds the 80% threshold (Bond et al., 2020; Linacre, 2022). The unexplained variance in contrasts 1 to 5 is less than 3%, also falling within the excellent category. This demonstrates that the instrument is free from significant measurement disturbances caused by external factors, thus ensuring that it validly measures creative thinking skills and is ready for practical application in the field.

Further analysis was conducted on item fit and item measure to assess the suitability and difficulty levels of each item. A well-fitting item is indicated by an MNSQ value between 0.5 and 1.5, with a point-measure correlation (PTM CORR) ranging from 0.4 to 0.85. When all three criteria are met, the item is categorized as "highly fit," meaning the item is of high quality and suitable for use. If only one or two of these criteria are fulfilled, the item is still considered "acceptable" and can be retained without revision. However, if none of the criteria are met, the item is labeled as "misfitting" and is deemed unsuitable, requiring revision or replacement (Dewi et al., 2021; Nurdini et al., 2020). A detailed summary of the item fit and item measure analysis is provided in Table 4.

Table 4. Rasch item fit and item measure analysis

No Item	Item fit				Pt. Measure Corr	Item Measure				Decision	
	Infit		Outfit			Infit		Outfit			
	MNSQ	ZSTD	MNSQ	ZSTD		MNSQ	ZSTD	MNSQ	ZSTD		
1.	0.75	-1.17	0.65	-0.71	0.83	1.03	0.20	0.94	0.07	0.82	Fit
2.	0.68	-1.26	0.66	-1.35	0.87	0.80	-1.35	0.76	-1.49	0.86	Fit
3.	1.07	0.48	1.05	0.34	0.90	1.14	0.88	1.12	0.64	0.91	Fit
4.	0.54	-1.39	0.52	-1.42	0.93	0.61	-1.80	0.57	-1.89	0.94	Fit
5.	1.01	0.13	1.01	0.12	0.84	1.21	1.32	1.24	1.40	0.84	Fit
6.	0.56	-1.99	0.54	-1.10	0.87	0.61	-1.61	0.57	-1.42	0.89	Fit
7.	0.69	-1.58	0.68	-0.42	0.82	0.87	-0.54	0.91	0.09	0.82	Fit
8.	1.21	1.26	1.19	1.10	0.77	1.50	1.45	1.47	1.37	0.77	Fit
9.	0.73	-1.70	0.72	-1.77	0.88	0.81	-1.17	0.77	-1.33	0.89	Fit
10.	1.41	2.14	1.18	0.48	0.69	1.46	0.63	1.48	1.19	0.70	Fit
11.	0.80	-1.21	0.80	-1.22	0.88	0.94	-0.32	0.95	-0.27	0.88	Fit
12.	0.73	-1.40	0.56	-1.31	0.85	0.88	-0.61	0.64	-0.89	0.84	Fit
13.	0.52	-1.41	0.50	-1.50	0.91	0.67	-1.21	0.64	-1.23	0.90	Fit
14.	0.55	-1.19	0.55	-1.11	0.90	0.69	-1.09	0.71	-1.77	0.90	Fit
15.	1.22	1.24	1.21	1.17	0.81	1.48	1.42	1.49	1.39	0.81	Fit
16.	0.64	-1.46	0.62	-1.55	0.85	0.74	-1.69	0.72	-1.44	0.85	Fit
17.	0.81	-1.45	1.03	0.25	0.84	0.85	-1.29	1.22	1.15	0.85	Fit
18.	0.87	-0.67	1.49	0.94	0.74	0.90	-0.54	1.44	1.86	0.77	Fit
19.	1.04	0.26	0.99	0.19	0.77	1.24	1.14	1.49	0.85	0.78	Fit
20.	0.66	-1.57	0.62	-1.70	0.91	0.72	-1.18	0.66	-1.33	0.91	Fit
21.	1.16	0.94	1.27	0.95	0.78	1.25	1.42	1.45	1.60	0.79	Fit
22.	0.75	-1.54	0.75	-1.52	0.89	0.85	-0.89	0.83	-0.92	0.89	Fit
23.	0.52	-1.46	0.51	-1.49	0.92	0.61	-1.72	0.58	-1.76	0.92	Fit
24.	1.10	0.70	1.16	0.99	0.81	1.37	1.39	1.46	1.49	0.79	Fit
25.	1.07	0.53	1.08	0.56	0.84	1.30	1.12	1.36	1.23	0.82	Fit

Based on Table 4, several items show point measure correlation (pt. measure corr.) values greater than 0.85, indicating that these items may overlap too closely with the main construct or are too similar to other items, which could lead to redundancy. In small samples, correlations that are too high may become unstable or biased due to limited data variation (Bond et al., 2020; Linacre, 2022). A point measure correlation above 0.85 suggests that the item may not fully capture diverse levels of student ability.

However, according to Rasch model guidelines, items are still considered acceptable if at least two of the three key criteria, MNSQ, ZSTD, and pt. measure corr. are within the recommended thresholds (Bond et al., 2020; Linacre, 2022). In this case, even though the pt. measure corr. exceeds the recommended value, the MNSQ (ranging from 0.5 to 1.5) and ZSTD (between -2.0 and +2.0) remain within acceptable limits, suggesting that the item still fits the Rasch model and does not need to be removed. MNSQ (Mean Square Fit Statistics) measures how well the item responses fit the Rasch model, with values close to 1.0 indicating an ideal fit. Values lower than 0.5 imply overfit, meaning the item is too predictable, while values above 1.5 suggest underfit, indicating inconsistency or noise in responses (Bond et al., 2020; Linacre, 2022). ZSTD (Z-standardized) complements MNSQ by showing whether the misfit is statistically significant, where ZSTD values between -2.0 and +2.0 are generally acceptable, especially for samples smaller than 250 respondents (Bond et al., 2020; Linacre, 2022).

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The findings of this study provide meaningful insights into the development and validation of a creative thinking assessment tool within the physics context, specifically related to fluid mechanics. To address the research question, the researchers present a brief answer in Table 5.

Table 5. Summary of Findings and Analysis Based on Research Questions

Research Question	Finding Summary	Discussion
What is the appropriate instrument to measure students' creative thinking skills?	This study introduces the SCI-Fi (Science Creative Instrument in Fluids) as a relevant and effective tool. The SCI-Fi instrument is designed based on the indicators of creative thinking adapted from the PISA 2021 framework, covering essential dimensions and expressions. The choice of an essay-based assessment with extended response format is particularly relevant as it allows students to explore open-ended responses, thereby reflecting higher-order creative thinking processes.	The PISA 2021 Creative Thinking Framework effectively measures creative thinking by focusing on three key processes: generating diverse ideas, generating creative ideas, and evaluating and improving ideas. This framework ensures that students are assessed not only on how many ideas they produce but also on the originality, relevance, and refinement of those ideas. By applying this model, the SCI-Fi instrument is designed to align with these processes through contextualized, open-ended tasks in the domain of fluid mechanics. The SCI-Fi enables students to express creative thinking in written form, encouraging them to propose varied solutions and justify improvements, making it an effective tool to capture both the generative and evaluative aspects of creative thinking in science education.
How can an instrument be developed to measure students' creative thinking skills?	An instrument to measure students' creative thinking skills can be developed by using a structured model, such as ADDIE, and referring to the PISA 2021 Creative Thinking Framework. This involves designing items that assess diverse idea generation, creative idea generation, and the ability to evaluate and improve ideas. In this study, the SCI-Fi instrument was developed using open-ended tasks related to fluid mechanics and was validated through Rasch analysis to ensure reliability and validity.	The development of the SCI-Fi instrument demonstrates that an effective creative thinking assessment must combine both sound pedagogical design and psychometric rigor. By using the PISA framework as a foundation, the instrument ensures comprehensive coverage of creative thinking processes. The use of open-ended questions allows students to explore and articulate ideas freely, fostering originality and critical evaluation. Implementing the ADDIE model enables structured development,

Research Question	Finding Summary	Discussion
		ensuring that the instrument aligns with learning objectives and scientific content, such as fluid mechanics. Finally, Rasch analysis confirms the reliability and validity of the items, making SCI-Fi a well-structured tool capable of assessing creative thinking beyond superficial idea generation. This development model is transferable to other disciplines where creative thinking is a crucial skill.
What are the validity and reliability levels of the developed instrument?	The SCI-Fi instrument demonstrates excellent validity and reliability, confirmed by high reliability indices and strong construct validity based on Rasch analysis.	The Rasch analysis shows a person reliability of 0.98 and an item reliability of 0.99, both categorized as excellent. The separation index values (6.76 for person and 11.76 for items) exceed the standard threshold of 2.0, indicating the instrument can clearly differentiate between varying levels of students' creative thinking skills. Additionally, unidimensionality is confirmed with 82.5% of raw variance explained, suggesting that the instrument consistently measures a single construct – creative thinking – without interference from external variables. These indicators collectively validate that SCI-Fi is a sound tool for educational assessment.
Is the developed instrument feasible for use?	The developed SCI-Fi instrument is feasible for use based on its validity, reliability, and alignment with assessment standards.	The SCI-Fi instrument is considered feasible as it fulfills both psychometric and pedagogical criteria. The Rasch model analysis confirms that the instrument meets the standards for item fit, reliability, and unidimensionality. In addition, the use of open-ended, context-based tasks makes the instrument practical for classroom application, particularly in physics learning related to fluid mechanics. Its alignment with the PISA 2021

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Research Question	Finding Summary	Discussion
		Creative Thinking Framework ensures that it effectively measures key dimensions of creative thinking. The high reliability and clear construct validity further reinforce its readiness for use in real learning environments to assess students' creative thinking development.

Comparing this approach to prior studies, most existing research has focused on the implementation of learning models such as STEM (Chai & Zhu, 2021) or problem-based learning (Ernawati et al., 2023), which aim to improve creative thinking but often overlook the development of robust measurement tools. The development of SCI-Fi addresses this gap by offering an assessment instrument that is directly aligned with creative thinking dimensions and expressions by PISA 2021 framework, fulfilling a need emphasized in the literature.

Considering the current findings, the SCI-Fi instrument can contribute to filling the gap in existing assessment practices, where many teachers rely on standard tests that may fail to capture higher-order thinking skills. This also aligns with Smith (2022) assertion that well-designed assessments should encourage students to engage in creative and critical thinking. Therefore, not only is the instrument valid and reliable, but it also meets the instructional demands of fostering creativity in science education. In addition, the SCI-Fi instrument is a psychometrically sound and pedagogically relevant tool for measuring students' creative thinking in physics, particularly within fluid mechanics.

The integration of the PISA 2021 Creative Thinking Framework into the SCI-Fi instrument marks a significant advancement, as it applies international standards to assess creative thinking through three cognitive processes: generating diverse ideas, generating creative ideas, and evaluating and improving ideas. Furthermore, the use of open-ended, contextualized essay tasks in the domain of fluid mechanics provides a more authentic and deeper assessment of students' higher-order thinking skills compared to traditional multiple-choice formats.

In this study, the focus was on key psychometric attributes, such as item validity, person/item fit, and reliability, to establish the fundamental measurement quality of the instrument. These attributes are essential in determining the internal consistency and structural soundness of a new assessment tool, particularly in early development stages (Bond et al., 2020; Linacre, 2022). Advanced diagnostics, including DIF and Wright Map analysis, were excluded as they extend beyond the primary aim of confirming the core psychometric properties of the developed assessment tool. While future studies may consider additional analyses such as DIF or Wright Map to further refine item functioning, the current version of the instrument is considered both effective and practical for educational use.

Although advanced diagnostics such as Differential Item Functioning (DIF) and Wright Map analysis were not conducted in this study, the Rasch model outputs provided sufficient evidence of unidimensionality and item coherence. This

prioritization distinguishes the present study from previous creative thinking assessments, which often lack psychometric validation altogether or rely solely on classical test theory.

Compared to general creativity tests such as the Torrance Tests of Creative Thinking (TTCT), which are widely used but not tailored to specific domains or subject matter (Chen & Peng, 2020; Lewis & Colonnese, 2021; Zimmerer et al., 2020), the SCI-Fi instrument offers a significant advancement by incorporating discipline-specific content, fluid mechanics, while maintaining rigorous psychometric standards. Unlike earlier tools that often neglect model-based validation or stop at face validity, this study ensures that each item aligns with Rasch model expectations, providing strong empirical support for its practical application in classroom settings.

The decision to exclude DIF and Wright Map analysis is based on the scope of this initial development phase, which emphasizes the establishment of core validity and reliability. Nonetheless, the instrument shows promising psychometric properties that justify its future refinement. Subsequent studies are encouraged to extend the analysis with DIF to examine potential bias across subgroups (e.g., gender or academic background), and with Wright Map to optimize item-person alignment (Linacre, 2022). Such expansions will enhance the robustness of SCI-Fi and further support its scalability for broader educational contexts.

Conclusion

This study successfully developed and validated the SCI-Fi instrument to measure students' creative thinking skills in fluid mechanics. The results demonstrate excellent reliability (person reliability = 0.98; item reliability = 0.99) and strong construct validity, confirmed by Rasch model analyses. The findings show that the instrument effectively captures essential creative thinking indicators aligned with the PISA 2021 framework. The novelty of this research lies in introducing a specialized, extended response instrument specifically designed for physics education, addressing a gap in prior studies that focused mainly on learning models rather than assessment tools. However, this study is limited by the absence of DIF and Wright Map analyses and a relatively small sample size. Despite these limitations, the SCI-Fi instrument is a valid, reliable, and practical tool for assessing creative thinking in science classrooms. Despite these limitations, the SCI-Fi instrument is a valid, reliable, and practical tool for assessing creative thinking in science classrooms. Its implementation can support teachers in diagnosing students' creative thinking profiles and designing targeted instructional interventions. Moreover, the SCI-Fi model offers a transferable framework that can inspire the development of similar domain-specific instruments in other areas of science education. This contributes to improving assessment practices that go beyond factual recall, fostering higher-order thinking skills essential for 21st-century learning.

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