

A systematic literature review on intuition: Its usefulness in physics learning and its relations to mathematical analysis and difficulties in understanding physics concepts

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ABSTRACT

This study aims to explore the usefulness of intuition in physics, to identify the relationships between intuition and mathematical analysis, as well as between intuition and the challenges faced in understanding physics concepts. The method utilized in this study was a systematic literature review (SLR). The SLR adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) flow diagram and guidelines. The literature reviewed consisted of articles in international journals published between 2007 and 2024. This study selected and reviewed 55 articles. The findings indicated three applications of intuition in physics learning, namely higher-level thinking, object identification, and cognitive development. There is an association between intuition and mathematical analysis, which serves as a process of understanding and discovery. Physics concepts are challenging to comprehend due to inconsistencies between perception and intuition, which require more analytical and logical abilities.

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Introduction

Physics is a part of science that is integrated with natural and/or physical phenomena in everyday life, e.g., boiling water, cooking food, driving a vehicle, and the increase of the Earth's temperature. These relate to the concepts of temperature and heat, thermodynamics, kinematics, dynamics, fluids, and many more through the laws of physics. However, the understanding of physics

concepts among the general public is still low (Kulgemeyer & Wittwer, 2023). The low understanding of physics indicates that it is considered a difficult subject at school (Palmgren & Rasa, 2024; Mbwile & Hegwa, 2025). This is because physics is only considered as a set of formulae that must be memorised such that its conceptual side is ignored and hence misconceptions often occur as learners are deprived of much-needed theory (Wittmann & Morgan, 2020; Vicovaro, 2023). It is necessary to cultivate learners' theoretical understanding of physics (Wu et al., 2024; Oral & Erkilic, 2022).

Intuition plays a crucial role in assisting learners as they confront difficulties in learning physics, although some of its concepts are counterintuitive, e.g., laws of motion. Intuition plays a crucial role in assisting them to link abstract concepts with their everyday experiences. As a result, learners can better understand the subject matter (Sherrin, 2006; Koerfer & Ye, 2024), implement physics principles in practical situations (Masin et al., 2014; Brock, 2015), reduce reliance on memorising formulas (Chang & Shieh, 2013), and focus more intently on a thorough understanding of physical phenomena (Körhasan & Gürel, 2019). Thus, studying physics is not just memorising and calculating but also using one's intuition.

Intuition allows learners to form an initial understanding based on their daily experiences, which then becomes the groundwork for articulating physics concepts in a more structured way. Intuition can be refined through contextual and exploratory learning, enabling learners to relate the phenomena they experience to the principles of physics (Corsiglia et al., 2023). This process can diminish the feeling of abstraction and the cognitive burden that often accompanies learning. The function of intuition not only simplifies the initial reasoning of learners but also assists in overcoming misconceptions and boosting confidence in tackling physics problems (Kalajian & Makarova, 2014; Suwanto et al., 2023). Learners employ intuition to make initial predictions before conducting formal calculations and they visualise phenomena that are difficult to observe directly. In physics, intuition is frequently intertwined with mathematical analysis, especially in problem-solving contexts (Kapodistrias & Airey, 2024). This is consistent with Yavuz's (2015) research, which reveals a cognitive connection between intuitive comprehension and mathematical skills in physics learning. Nevertheless, intuition is often not completely accurate and can result in mistakes (Kirkebøen & Nordbye, 2017; Miller, 2018). Consequently, intuition should be further cultivated through formal education and accompanied by strategies for reflecting on intuitive responses (Koerfer & Ye, 2024).

Studying physics is important as a means of refining the ability to think and make decisions. One of the thinking abilities that can influence the physics learning process is intuition. Based on the findings of literature searches, intuitive abilities can be used in identifying physical objects (Wong et al., 2023), relating mathematical abilities (Yavuz, 2015), and reducing the difficulty of understanding physics (Gette & Kryjevskaja, 2019). Nevertheless, further extensive research is required to understand the role of intuition in the context of physics education as it is related to cognitive development and contextual understanding. The review undertaken may offer valuable contributions by investigating and assessing the degree to which intuition has been applied and advanced in the teaching of physics. As a result, this research not only enhances our understanding but also offers a more comprehensive perspective on the pedagogical implications of intuition and its application in enriching the quality of physics learning in a more profound way.

Historically, discussions about intuition from within a theoretical-philosophical framework began at the beginning of the 20th century. The concept of intuition has been applied in various fields, such as education (Sipman et al., 2024), management (Korherr et al., 2023), business (Brown et al., 2015), and medicine (Müller et al., 2024). The concept of intuition began to be used in psychology with the controversy between analysis and intuition using the same processing system. Furthermore, based on the split-brain theory, intuition can be used by everyone and is not used only by experts (Shtulman, 2014). Research on intuition-based learning began in Western Europe at the end of the 19th century (Sahlfeld, 2018). The concept of intuition has been used in morality issues where the results of moral judgments depend on a combination of analysis and intuition (Julmi, 2024; Sosa et al., 2021). Intuition is shaped by one's experiences, knowledge and emotions (Isenman, 2018). Numerous significant discoveries have emerged from intuition. Scientists frequently derive inspiration for complex

problems through intuitive insights (Monsay, 2016). Initially, scientific discoveries are not solely reliant on data and deduction. Intuition plays a crucial role in the scientific discovery process (Welch et al., 2007). For instance, the intuition of early 20th-century physicists provided fundamental insights that led to the discovery of quantum mechanics, exemplified by Max Planck's introduction of the concept of energy quantization (Sakho, 2019). Although intuition is sometimes perceived as irrelevant and even unscientific, history illustrates that it is central to the scientific process (Burnett & Francisco, 2020). However, a deep understanding of intuition in learning is important for further studies.

There have not been many studies on intuition, especially in physics learning. Physics is closely related to natural phenomena. Natural phenomena that occur in everyday life can be studied by involving intuition (Monsay, 2016; Sipman et al., 2024). However, the many formulas in physics require a deeper understanding, reasoning, and mathematical analysis. Thus, abilities are needed that can bridge between everyday experience and logical reasoning (Bancong & Song, 2020). One ability that can bridge these gaps is intuitive reasoning. In the learning process, intuition is used as a support for a physical theory (Piloto et al., 2022; Tallant, 2015). Intuition in physics has an important role, especially in learning, i.e., to provide insight into scientific processes and decision-making (Tallant, 2013; Fischer & Mahon, 2021). This intuition becomes a starting point for students to understand situations (Buteler & Coleoni, 2014), solve problems (Rahmah et al., 2020), and understand physical phenomena correctly (Kubricht et al., 2017). This argument is in line with the findings of Seo & Lee (2021) who found that studying physics allows someone to predict and explain natural phenomena. Therefore, it is necessary to conduct a literature review regarding the use of intuition in physics, determining the relationships between intuition and mathematical analysis, and between intuition and the difficulty of understanding physics concepts.

Although intuition is crucial for enhancing conceptual understanding, pedagogical approaches to it remain fragmented and poorly structured in the existing literature. Consequently, this literature review is essential for systematically exploring how intuition has been defined, examined, and applied across various contexts in physics education. This review also aims to elucidate the relationship between intuition and other cognitive processes, such as mathematical reasoning, concept formation, and problem-solving. This study not only reinforces the urgency for further research on intuition in physics education but also provides a solid foundation for subsequent empirical studies aimed at more effectively integrating intuitive and formal thinking in learning practices that have not been previously undertaken. Prior studies have predominantly focused on one aspect, namely intuition. This study serves as a reminder that intuition in physics learning is utilized to address difficulties and assist in problem-solving. Additionally, this study offers pedagogical recommendations based on the latest literature and a thematic synthesis of previously scattered research findings. Based on the above description, the research questions (RQs) are formulated as follows:

- 1) How is intuition used in physics learning?
- 2) How are intuition and mathematical analysis related?
- 3) How can intuition remedy the difficulty in understanding physics concepts in physics learning?

Methods

This is a systematic literature review (SLR) study. The SLR was used to identify, evaluate and synthesise research results and thoughts of previous researchers (Brunton et al., 2020). Several stages had been conducted to produce the results of the review, namely a) selecting the topics to be reviewed, b) defining and formulating the RQs, c) searching for relevant articles, d) selecting relevant articles through identification, filtration and feasibility, e) analysing, synthesising, and summarising information to answer the RQs, and f) writing reviews.

This study examined the use of intuition in the physics learning process. To achieve this, identifying the needs for reviews was conducted. Identification was related to studies that were

carried out first before conducting a systematic review. Review identification was used to clarify and explore findings related to research on the use of intuition (Siddaway et al., 2019; Chigbu et al., 2023). In this case, it was necessary to carry out systematic reviews and mapping. Based on the identification of needs, it was found that no similar research related to this review had been conducted. Therefore, previous research had not answered the RQs undertaken in this SLR. This was because the articles found and chosen focused on how someone without formal education can understand physical phenomena intuitively. The study highlighted how individuals, particularly students and the general public, can understand physical phenomena through intuitive reasoning, even before prior to receiving formal education.

A discussion regarding a review of physics intuition was published in 2013 (Tallant, 2013). To the best of the authors' knowledge, there has been little to no discussion regarding the use of intuition in physics learning since then. The absence of such discussion revealed a significant gap in the attempts to unify and delineate the recent research trends regarding intuition in physics education, particularly in light of the current educational paradigm. Moreover, this review could provide a basis for future research endeavors, motivating academics to investigate delve into the cognitive processes that inform intuitive reasoning in physics and their implications for learning outcomes. This extensive review aimed to reinvigorate the dialogue on intuition within physics education and to open avenues for innovative teaching methodologies that have historically prioritized analytical thinking.

The next step was determining the RQs. There were three RQs that have been formulated in this study as follows:

RQ1: How was intuition used in physics learning?

RQ2: How were intuition and mathematical analysis related?

RQ3: How can intuition remedy the difficulty of understanding physics concepts in physics learning?

This literature review examined the distribution of databases, years, education levels, countries, and physics topics that discussed intuition. This was formulated in the mapping questions (MQs). The MQs were aimed at establishing the context of the SLR and assisting in the definition of RQs as well as being a source of selection criteria (Hannousse & Yahiouche, 2021). Moreover, a synthesis matrix was prepared to identify and classify the data sources used. This SLR examined findings made from 2007 to 2024 regarding intuition in physics learning. There were five MQs that have been formulated as follows:

MQ1: Which published studies were related to intuition in physics learning?

MQ2: What was the distribution regarding intuition in physics research per year?

MQ3: Which levels had applied intuition in physics learning?

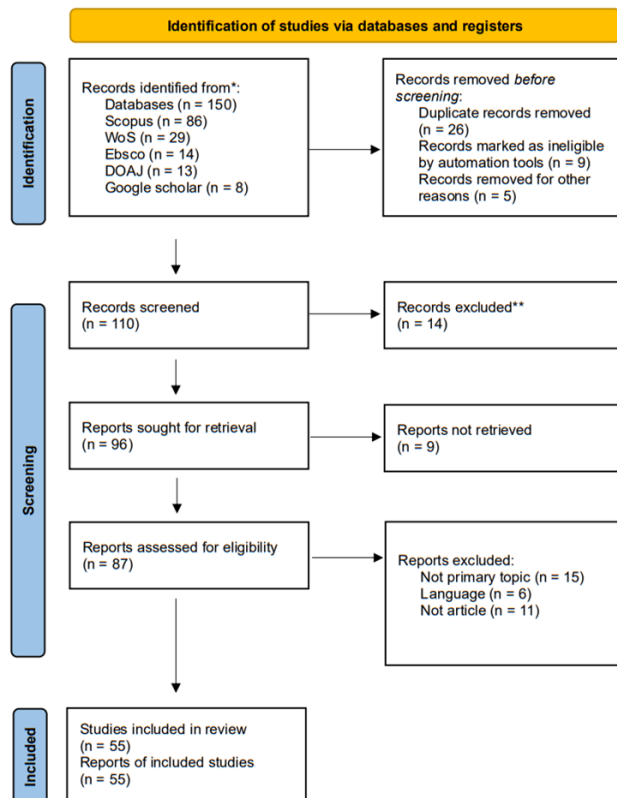
MQ4: In which countries was this research conducted?

MQ5: In what physics topics were intuition applied?

Next, searches for relevant sources were conducted. In establishing credibility, the researchers employed the technique of source triangulation by gathering data from various reputable databases. A collection of literature was obtained from various sources via Scopus, Web of Science (WoS), Ebsco, Directory of Open Access Journals (DOAJ), and Google Scholar. In addition, the construction of confirmability was maintained in chronological order (auditable trail), starting with the literature search process, article selection, data extraction, and analysis. Moreover, the researchers clearly outlined the steps taken from the reviewed studies and engaged in researcher reflection. This process was further undertaken to ensure that the findings were based on data rather than the researchers' assumptions, thereby avoiding potential subjective bias.

Figure 1

The steps of the SLR method using the PRISMA guideline



Finally, the study adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and flow diagram to outline the processes in stages d) and e). PRISMA is a guideline for reporting systematic reviews to improve review quality and clarify research findings (Moher et al., 2010; Liberati et al., 2009). The steps of the SLR method using PRISMA are shown in Fig. 1.

There were four steps in the PRISMA guidelines, namely identifying research reviews, filtering articles with relevant sources, assessing articles for eligibility, and reporting the results of the final included articles. The identification of relevant literature was carried out by limiting the keywords used, i.e., intuition in physics, uses of intuition, and physics learning. A total of 150 articles were obtained, with the highest number of 86 articles coming from Scopus. The results of article identification based on search strategy decisions can be seen in Table 1.

The next step was article filtration based on the study selection criteria reviewed using the inclusion and exclusion method. The inclusion criteria were those used to select articles to be studied, while exclusion criteria were those used to eliminate articles that do not match the subject matter (Ismail & Yusof, 2023). Clear inclusion and exclusion criteria were utilised to ensure that only relevant and high-quality studies were analysed. The criteria used can be seen in Table 2. The inclusion and exclusion criteria outlined in Table 2 were selected to ensure methodological quality, source traceability, and compliance with international academic standards, specifically focusing on articles published in English and indexed in certain databases. This was due to the study's emphasis on literature that was recognised internationally. During the filtering step, 26 articles were identified as duplicates that needed to be deleted. This step ended up with a total of 87 articles with 63 articles eliminated because they did not meet the criteria presented in Table 2. In addition, several articles also did not have open access to the public.

In the subsequent step of assessing articles for eligibility, a total of 67 articles were found. Articles were selected with high relevance criteria according to the RQs. Thus, a total of 55 articles

were selected to be reported in the final results and reviewed in the fourth step. The review carried out was by answering the RQs and analysing the novelty of research concerning intuition in physics learning carried out over 18 years (2007-2024). Next, the fifth step was to analyse, synthesise, and summarise the information needed to answer the RQs using a synthesis matrix. The synthesis matrix was used to organise the literature sources and integrate them with the unique research findings.

Table 1*Search strategy decisions*

Criteria	Information
Databases	Scopus (https://www.scopus.com/), WoS (https://mjl.clarivate.com/), Ebsco (https://www.ebsco.com/), DOAJ (https://doaj.org/), and Google Scholar (https://scholar.google.com/).
Items	Journal articles.
Search applied on	Article titles, keywords, abstracts, and subject areas.
Publishing period	From July 2007 to August 2024.

Table 2*Inclusion and exclusion criteria*

Inclusion Criteria	Exclusion Criteria
Includes primary studies related to the RQs.	Not in accordance with the study to be reviewed.
Publication years 2007-2024	Publication year under 2007.
Articles related to intuition in physics and the uses of intuition.	The article was not concerned with intuition in physics and the use of intuition.
Types of research articles or reviews published in scientific journals.	The research articles or reviews were not published in scientific journals, e.g.: conference proceedings, books, theses, and dissertations.
Use English.	Does not use English.

Results

Synthesis Matrix

This study examines a total of 55 articles that have high relevance to the topic discussed, namely intuition in physics learning. The synthesis results are shown in Table 3.

Table 3

Examples of high relevance articles in the synthesis matrix

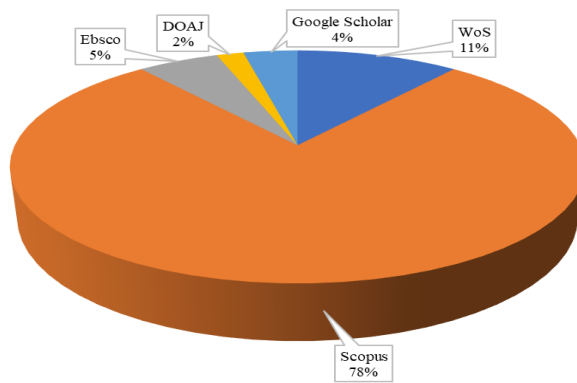
Reference	Title	Year	Population	Findings
Corsiglia et al., 2023	Intuition in quantum mechanics: Student perspectives and expectations	2023	University	There is a relationship between intuitive abilities and students' effort. Intuitive abilities can increase students' efforts in studying physics material, but intuitive abilities do not affect academic grades or learning outcomes.
Ludwin-Peery et al., 2020	Broken physics: A conjunction-fallacy effect in intuitive physical reasoning	2020	General (aged 33-34 years old)	Humans have the ability to understand and predict the behaviour of physical objects based on experience and intuitive knowledge. In addition, physics intuitive abilities also depend on how information is presented and understood.
Bickart, 2024	The possible role of intuition in education	2024	Primary school	Pupils can have an intuitive and holistic understanding of natural phenomena by observing and perceiving a natural phenomenon as a whole.
Ricardo, 2016	Comprehensive analysis of the failure of intuition in elementary rigid body dynamics	2016	Senior high school	Analytical steps to overcome misconceptions in students' ways of thinking and failure of intuition in solving physics problems require a mathematical approach. Sometimes mathematical analysis is counterintuitive to everyday experience.
Park & Song, 2020	How is intuitive thinking shared and elaborated during small-group problem-solving activities on thermal phenomena?	2020	Primary school	It is important to understand the relationship between intuitive thinking and logical thinking in the context of physics education. Both complement each other and can improve pupils' abilities in solving problems.

A Database That Publishes Studies Related to Intuition in Physics Learning

The collection of literature sources in this study uses databases indexed by Scopus, WoS, Ebsco, DOAJ, and Google Scholar. There are 55 articles from international journals reviewed in this study. The percentage results of the search database usage related to intuition in physics learning can be observed in Fig. 2. Based on Fig. 2, it can be seen that the largest database search result is Scopus, with a percentage of 78%. This indicates that more than half of the studies on intuition in physics learning have been indexed by Scopus.

Figure 2

Percentage of intuition in physics search databases

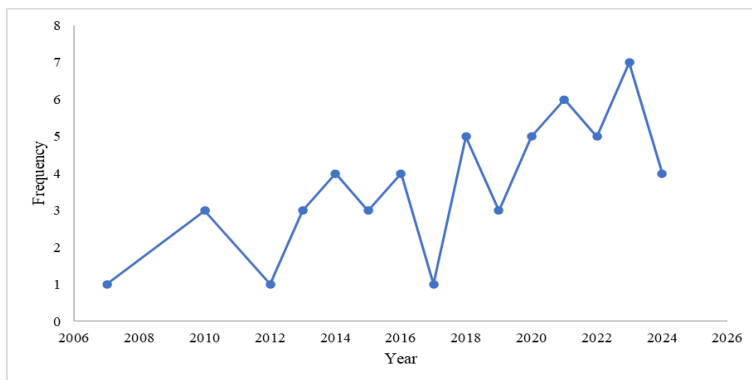


Distribution Related to Intuition in Physics Learning Research Per Year

This study examines the development of intuition in physics learning from July 2007 to August 2024. The graph of the distribution of intuition in physics learning research can be seen in Fig. 3. The study of intuition in physics learning is less discussed from 2007 to 2017. Meanwhile, it begins to be discussed, and a significant increase in the study is seen from 2018 to 2023. Based on Fig. 3, it can be seen that most studies on intuition in physics learning were in the year 2023. The findings in 2023 examine the use of intuition in physics learning, the relationship between intuition and mathematical analysis, and the use of intuition to remedy the difficulty in understanding physics concepts.

Figure 3

Distribution of intuition in physics learning research from 2007 to 2024

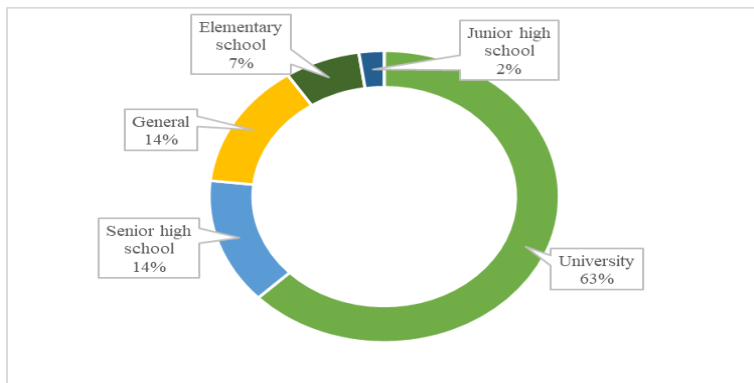


Educational Levels That Apply Intuition in Physics Learning

Intuition in physics learning has been examined at several levels of education in various countries, from primary school to university. Intuition in physics learning has been widely applied at the university level with a percentage of 63%. This can be observed in Fig. 4. The search results also show that intuition in physics learning has been previously researched at a general level with a percentage of 14%. The general level in this study refers to one who has not received formal education but meets certain age criteria.

Figure 4

Distribution of educational levels applying intuition in physics learning

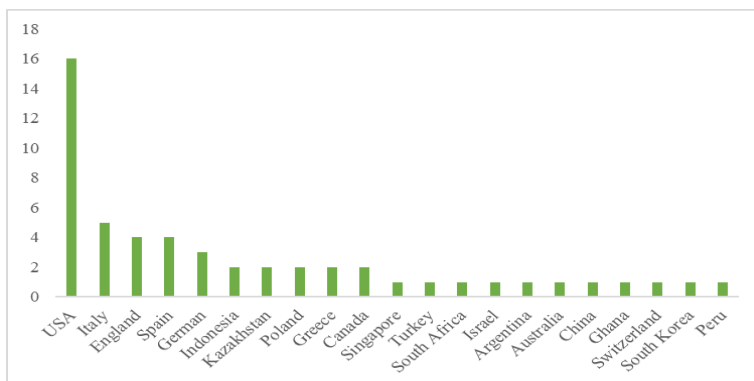


Countries Where Intuition in Physics Learning Has Been Studied

Studies on intuition in physics learning have been conducted in 21 countries, including Indonesia. The country that has made a major contribution to this topic is the United States (US). Three countries that have studied intuition in physics learning after the US are Italy, England, and Spain. Studies on this topic are still rarely carried out in Indonesia, even though intuition plays a role in solving physics problems (Farmaki & Paschos, 2007; Resbiantoro et al., 2022), increasing creativity (Tallant, 2013), acting as a support for a theory (Okoli & Watt, 2018), and providing insight into the scientific process (Tallant, 2015). The distribution of countries studying intuition in physics learning is shown in Fig. 5.

Figure 5

Countries that study intuition in physics learning



Physics Topics That Apply Intuition

The percentage of physics topics that use intuition is shown in Fig. 6. Based on the figure, the highest percentage of intuition is used in kinematics, i.e., 52%. Studies on kinematics are shown in Table 4. Researchers have studied intuition-related kinematics, such as gravitational force (Ludwin-Peery et al., 2021; Wong et al., 2023; Assem et al., 2023; Król, 2020), Newton's law (Yavuz, 2015; Vicovaro, 2018; Vicovaro, 2021; Gette & Kryjevskaja, 2019), free fall motion (Vicovaro, 2014), momentum and impulse (Kubricht et al., 2017), general motion of objects (Ludwin-Peery et al., 2020; Vicovaro, 2023), and Newtonian mechanics (Sanborn et al., 2013), as well as elasticity (Vicovaro & Burigana, 2016). Intuition studies are still rarely carried out on oscillation (Smith et al., 2018), optics (Vicovaro, 2023), thermodynamics (Park & Song, 2020), vectors (Carli et al., 2020), and electric current (Kryjevskaja et al., 2014).

Figure 6

The use of intuition in physics topics

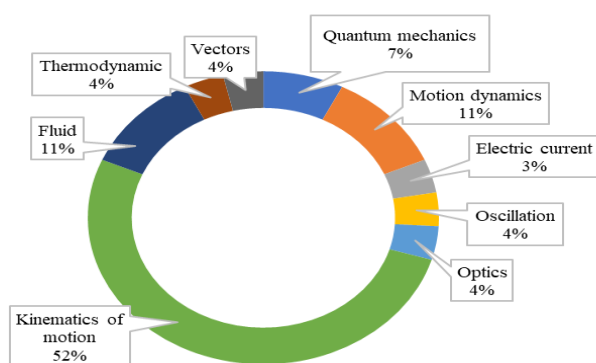


Table 4

Physics topics in various literatures that involve intuition

Physics topics	Quantity	Author
Kinematics (gravitational force, Newton's law, free fall motion, momentum, object motion, Newtonian mechanics, elasticity)	14	Vicovaro, 2021; Ludwin-Peery et al., 2020; Ludwin-Peery et al., 2021; Vicovaro, 2023; Wong et al., 2023; Vicovaro, 2018; Vicovaro, 2014; Yavuz, 2015; Lemmer, 2013; Sanborn et al., 2013; Gette & Kryjevskaja, 2019; Vicovaro & Burigana, 2016; Assem et al., 2023; Król, 2020.
Fluid (capillarity, Archimedes's law)	3	Buteler & Coleoni, 2014; Buteler & Coleoni, 2012; Bates et al., 2019.
Motion dynamics	3	Ludwin-Peery et al., 2021; Fischer & Mahon, 2021; Ricardo, 2016; Ospanbekov et al., 2024.
Quantum mechanics	2	Corsiglia et al., 2023; Bouchée et al., 2022.
Others (oscillation, optics, electric current, thermodynamics; vectors)	5	Vicovaro, 2023; Kryjevskaja et al., 2014; Smith et al., 2018; Park & Song, 2020; Carli et al., 2020.

The Use of Intuition in Physics Learning

The findings regarding the use of intuition in the learning of physics can be observed in Table 5. Based on the findings, the use of intuition in physics learning is categorised into three aspects, namely higher-level thinking, object identification, and cognitive development. There has been quite a lot of research regarding the use of intuition in physics learning as a cognitive development. Cognitive development refers to learners' abilities to understand (Vicovaro, 2021; Tallant, 2013), process

information (Corsiglia et al., 2023; Mitko et al., 2024; Tallant, 2015; Mayer & Maree, 2017), solve problems (Vicovaro, 2018; Eshach & Kukliansky, 2018; Sinclair, 2010; Park & Song, 2020), and interact with the environment (Vicovaro, 2023; Villoro & Estaun, 2018).

Table 5

Use of intuition in physics learning

The use of intuition	Quantity	Author
High level thinking	6	Wong et al., 2023; Ospanbekov et al., 2024; Kryjevskaia et al., 2014; McCoy & Ullman, 2019; Pétervári et al., 2016; Grève, 2023.
Object identification	7	Ludwin-Peery et al., 2020; Ludwin-Peery et al., 2021; Fischer & Mahon, 2021; Kalajian & Makarova, 2014; Wong et al., 2023; Neupärtl et al., 2020; Bates et al., 2019.
Cognitive development	12	Vicovaro, 2021; Corsiglia et al., 2023; Tallant, 2013; Vicovaro, 2023; Vicovaro, 2018; Eshach & Kukliansky, 2018; Mitko et al., 2024; Tallant, 2015; Sinclair, 2010; Mayer & Maree, 2017; Villoro & Estaun, 2018; Park & Song, 2020.

The Relationship between Intuition and Mathematical Analysis

This study finds that there are three relationships between intuition and mathematical analysis, namely the process of understanding, the process of discovery, and the application of mathematical concepts. The findings of the relationship between intuition and mathematical analysis can be observed in Table 6. Based on Table 6, the findings show that intuition as a process of understanding makes the biggest contribution in mathematical analysis.

Table 6

Intuition and mathematical analysis relationship

Relationship aspect	Quantity	Author
Understanding process	9	Bickart, 2024; Buteler & Coleoni, 2014; Polcyn, 2023; Longo & Viarouge, 2010; Farmaki & Paschos, 2007; De Toffoli, 2021; Malaspina & Font, 2010; Król, 2020; Shtulman & Young, 2024.
Discovery process	6	Baiduri & Ulfah, 2022; Brock, 2015; Müller, 2024; Vicovaro & Burigana, 2016; Zhang et al., 2016; Grehl & Tutić, 2022.
Application of mathematical concepts	5	Ricardo, 2016; Popova et al., 2022; Yavuz, 2015; Gisin, 2021; Carli et al., 2020.

Exploring Difficulties in Understanding Physics Concepts

The physics subject has many formulas and abstract concepts that have to be memorised and also understood. This causes students to have difficulty understanding physics concepts. This study deduces that there are three reasons why studying physics is difficult. The review results of exploring difficulties in understanding physics concepts can be observed in Table 7. Table 7 indicates that eight articles regard physics as a difficult subject to understand. This can be caused by lack of practice, experience, and limited learning resources. Furthermore, seven articles identify inconsistencies between perception and intuition that make physics difficult. Finally, six articles in Table 7 report that certain physics topics require analytical and logical skills that students consider difficult to master.

Table 7*Difficulties in understanding physics concepts*

Physics difficulty	Quantity	Author
Hard to understand	8	Sanborn et al., 2013; Ludwin-Peery et al., 2021; Vicovaro, 2023; Bouchée et al., 2022; Friederich et al., 2021; Assem et al., 2023; Resbiantoro et al., 2022; Carli et al., 2020.
Inconsistency between perception and intuition	7	Vicovaro, 2014; Yavuz, 2015; Lemmer, 2013; Gette & Kryjevskaia, 2019; Smith et al., 2018; Assem et al., 2023; Resbiantoro et al., 2022
Uses analytical and logical skills	6	Ricardo, 2016; Ludwin-Peery et al., 2020; Corsiglia et al., 2023; Park & Song, 2020; Okoli & Watt, 2018; Bickart, 2024.

Discussion

Usefulness of Intuition in Physics Learning (RQ1)

The body of research on intuition in physics learning has expanded significantly in the US, as shown in Fig. 5. However, there is a paucity of research on intuition in physics learning in other countries, including Indonesia. Several reasons these studies remain limited include a lack of emphasis on intuition in the curriculum, fewer teaching approaches that integrate it, limited resources, and a general lack of awareness of its importance. Table 5 summarises the perceived utility of the intuition identified in this study.

Firstly, the usefulness of intuition is related to high-level thinking. In physics learning, especially in solving physics problems, the higher a student's thinking ability, the more refined their physical intuition must be (Grève, 2023). By making effective use of their intuition, students can make sound judgments and decisions. An example of this is described in the study of Ospanbekov et al. (2024), where Kazakh students were presented with counter-intuitive dynamics problems through peer instruction. Interestingly, more students switched from correct to incorrect answers after the group discussion. In addition, the more strikingly a question contradicts everyday experience and/or the stronger the counter-intuitive elements, the more problematic the question becomes for students. In this case, intuition is used to simulate the physical phenomena in the problem. However, not all students can do this task because each student's initial physics abilities vary. This is supported by research by Kryjevskaia et al. (2014); McCoy & Ullman (2019); and Pétervári et al. (2016), showing that intuition in physics becomes increasingly important when problems in physics require students to use creative thinking, critical thinking, problem solving, and logical reasoning. Students tend to apply ideas selectively to support conclusions that can improve reasoning. However, even for lower-order thinking skills (LOTS), intuitive abilities can be used, especially in recognizing or identifying physical objects, such as studying interactions between (thin) fabric, gravity, and objects (Wong et al., 2023). The results of the present study show that visual representation abilities can be trained using intuition to learn the structure of objects in more depth.

Second, intuition has an important role in physics learning, especially in the process of identifying objects. By using intuition, students can relate physics objects to everyday experiences. This is supported by research by Ludwin-Peery et al. (2020) and Wong et al. (2023), which suggests that students can understand and predict physical objects based on their experience and intuitive knowledge. Of course, this can facilitate the understanding of physics principles in a real context, even though it does not always produce accurate predictions and may contradict actual results (Ludwin-Peery et al., 2021; Kalajian & Makarova, 2014). However, to minimize these errors, Science, Technology, Engineering, and Mathematics (STEM) can be used as a learning approach that allows students to use intuition in the learning process actively and interactively (Fischer & Mahon, 2021). Through the STEM approach, students can be encouraged to strengthen intuition by developing a product based on experience and information obtained from the surrounding environment. In addition, it is important to integrate students' intuitive experiences with theoretical knowledge by

providing phenomena related to everyday experiences (Neupärtl et al., 2020). Thus, teachers need to design activities that encourage students to explore their intuition using project-based learning (PjBL) or problem-based learning (PBL) models (Bates et al., 2019).

Third, intuition plays an important role in students' cognitive development. In general, cognitive development includes the ability to understand, process information, solve problems, and interact with the environment. Basically, intuition helps students link theoretical concepts to practical experience, in which the environment stimulates deep implicit cognition or automatic processing (Vicovaro, 2023; Villoro & Estaun, 2018). Intuition is a form of knowledge that is manifested as awareness of thoughts, feelings, and observations (Mayer & Maree, 2017). When students apply their intuition to understand physical phenomena, they rely on memory, engage in active thinking, and gain insights into scientific processes (Tallant, 2013). Furthermore, cognitive development can be influenced by age. Children's intuitive understanding of physics develops with age, which can influence cognitive growth (Vicovaro, 2021). However, it does not rule out the possibility that, in adulthood, students still sometimes ignore their initial intuition when studying physics (Corsiglia et al., 2023). For example, when facing errors and uncertainty in physics laboratory activities, students with less laboratory experience tend to utilise intuition compared to students with more laboratory experience (Eshach & Kukliansky, 2018). This shows that physical intuition functions as a tool for understanding physical interactions and as a basis for a more complex understanding in solving problems (Vicovaro, 2018). Furthermore, intuition can be derived from theoretical explanations, images, thought patterns, and experiences (Tallant, 2015; Mitko et al., 2024). In the context of physics, experience and experimentation can help students develop better intuition about physics concepts (Park & Song, 2020). If intuition is applied correctly, it can mitigate misconceptions, especially in physics (Sinclair, 2010). Thus, intuition plays a role in supporting a theory in physics.

The development of research on intuition in physics learning has occurred at elementary, middle and high school, university, and general levels. Based on Fig. 4, at the university level, the percentage is 63%. This shows that investigations into physics intuition abilities are more developed at the university level than at other levels. For university students, the use of intuition can help them to understand abstract concepts that are not visible in everyday life, such as quantum physics (Corsiglia et al., 2023). However, intuition needs to be applied from an early age. This can help students understand basic physics concepts related to everyday life better and develop creative thinking abilities with physics materials. Thus, at other education levels such as elementary, middle, and high schools, intuition still needs to be introduced. Having good intuition will create a strong foundation for more complex understanding. Furthermore, physics helps reveal the mechanisms behind falling objects, forces, vehicle movements, collisions, and other everyday situations. Some of these phenomena are related to kinematics. This is in line with Fig. 6 in that the study of intuition is quite widely applied to kinematics materials because they are often encountered in everyday life.

Relationship between Intuition and Mathematical Analysis (RQ2)

Physics is closely related to mathematical analysis because the field utilises various formulas and equations. Linking the ability of intuition in physics learning produces a relationship between intuition and mathematical analysis (physics equations). The present study summarises the relationship between intuition and mathematical analysis in three aspects: understanding processes, discovery processes, and mathematical applications. First, in understanding processes, one has an intuitive and holistic understanding of natural phenomena (Bickart, 2024). Natural phenomena can be well understood from a physics perspective by providing scientific explanations through mathematical equations. According to Buteler & Coleoni (2014), the use of equations or formulas can contribute to improving intuition. On the other hand, physics intuition is based on everyday experience and observations of physical phenomena (Malaspina & Font, 2010; Król, 2020). However, each person's intuition can differ and cause errors (Polcyn, 2023). Additionally, intuition can result in inconsistencies with physical facts or observations, or even more strongly, intuitive knowledge is a

collection of prejudices or misconceptions (Sherrin, 2006; Shtulman & Young, 2024). Therefore, students and/or teachers should rely more on mathematical analysis in solving physics problems and/or questions (Farmaki & Paschos, 2007; De Toffoli, 2021). As physics problems and/or questions become more complicated, intuition becomes less reliable than mathematical analysis even though mathematics itself actually also uses intuition (Longo & Viarouge, 2010).

Second, in the discovery process, intuition plays a critical role in uncovering and understanding mathematical concepts and analyses (Vicovaro & Burigana, 2016). This helps students develop ideas and concepts before carrying out analytical processes in physics learning. Intuition can open up innovations, hone students' creativity, and help students to make decisions (Müller, 2024; Zhang et al., 2016; Grehl & Tutić, 2022). The trustworthiness of mathematical analysis shows that mathematics is more convincing than verbal and intuitive descriptions. Additionally, some students believe that intuition often leads to wrong conclusions in physics. However, students who use intuition to solve physics problems believe that intuition is not misleading. In general, the evidence suggests that intuition can be a process that is both inhibiting and productive (Brock, 2015). In physics learning, intuitive abilities may be influenced by gender. On the one hand, male students use intuitive thinking processes constructively. Meanwhile, , female students may use intuitive thinking with guessing and double-checking strategies (Baiduri & Ulfah, 2022). This shows that male students tend to build their intuitive abilities, while female students tend to test their intuitive abilities in solving mathematical problems.

Third, in terms of application of mathematical concepts, based on the study by Popova et al. (2022), mathematical intuition and logic have a positive influence on students' implementation of mathematical concepts. Effective strategies such as memorization, PBL, realistic mathematics learning approaches, mathematical reasoning, and analogical learning models are very useful for improving mathematics learning skills and intuitive thinking abilities. Apart from that, using a mathematical approach becomes an analytical step to overcome students' misconceptions in solving problems (Ricardo, 2016). Regarding the use of intuition and/or mathematical calculations to solve physics problems, Yavuz (2015) reports that 57% of students trust their intuition, compared with 43% who trust mathematical calculations. However, students who trust mathematical calculations have higher physics achievement scores than students who trust their intuition. This means that mathematical understanding does not always convert well into understanding physics (Carli et al., 2020). However, Gisin (2021) shows that mathematical concepts are close to human intuition and make physics more understandable and relevant to everyday experience. As an example of applying mathematical concepts, Yavuz (2015) uses an epistemic game-theory framework to explain the procedures participants use to solve physics problems. Students are given Elby-pair problems that involve a drag race between a vehicle with a load and an additional cart. In this case, intuition and mathematical calculations can be applied simultaneously, and both complement each other (Yavuz, 2015; Sherrin, 2006). Similarly, intuition can form the context for interpreting the results of mathematical calculations in physics learning.

Exploring Difficulties in Understanding Physics Concepts (RQ3)

A persistent challenge in physics education is that students still experience difficulties in understanding them. Various studies have been conducted regarding improving physics learning outcomes at the junior and senior high school levels. Even though there is a lot of research on developing models and approaches, physics is still considered a difficult subject for both school and university students. In this case, abilities are needed that involve subconscious, spontaneous, and global experience without going through systematic analysis to minimise the difficulties of understanding the physics concepts, i.e., intuition. However, research examining the role of intuition to remedy the difficulties in understanding physics concepts is still rare. Intuitive thinking is different from creative thinking. Creative thinking focuses on generating new ideas and the thinking process is more structured. However, the two are interconnected in the context of problem-solving and

exploring the difficulties of physics concepts. Intuition acts as an initial driver in the creative thinking process. Via intuition, one can understand something without thinking deeply about it (Wong et al., 2023). In this case, intuition is used as a bridge between practical experience and theoretical understanding.

This review produces several findings regarding understanding physics concepts, including physics being difficult to understand, inconsistencies between perception and intuition, and the role of analytical and logical skills. First, physics is hard to understand. The large number of complicated formulas, confusing variations of questions, and lack of supporting media make physics difficult for students to understand. Apart from that, students also have not found the reason why it is important to study physics. This is a fundamental reason why physics concepts are difficult to understand. Based on research by Sanborn et al. (2013), a deep understanding of physics is often hampered by limitations in information processing and lack of experience. Limited cognitive understanding and misconceptions in a student's way of thinking can also hinder learning physics (Ludwin-Peery et al., 2021; Vicovaro, 2023). Some physics materials are considered abstract and cannot be observed directly, such as particles, waves, and quantum states (Bouchée et al., 2022; Friederich et al., 2021). Thus, there is a critical need for more interactive, understanding-based teaching methods that can help overcome the difficulties of learning physics, avoid incorrect intuitions, and build deeper knowledge (Assem et al., 2023). In this case, teachers need to design more effective learning strategies such as simulation-based experiments, conceptual change texts, PjBL, and inquiry-based learning (Resbiantoro et al., 2022). These learning strategies are designed to build strong intuition (Carli et al., 2020).

Second, there is an inconsistency between perception and intuition. Physics has many abstract concepts and requires consistent understanding. Inconsistent perception can cause students' intuition to be unstable. This leads students to develop an ambiguous and incorrect understanding of the concepts being studied (Yavuz, 2015). Furthermore, there is an inconsistency between students' intuitions based on observations and physical conceptions (Lemmer, 2013; Gette & Kryjevskaja, 2019). This is exacerbated when the teacher lacks well-developed intuitive abilities in physics concepts. This intuitive error is carried over to students because erroneous thinking is often not fully erased even after they receive appropriate training and/or instruction in the physics concepts (Vicovaro, 2014; Smith et al., 2018). For example, research by Assem et al. (2023) and Resbiantoro et al. (2022) notes a common misunderstanding regarding the force of gravity and the direction of movement, in which students hold an inaccurate view of the forces acting on objects that are thrown up and then fall back down. Several studies show that using learning methods that integrate intuition can help students reduce misconceptions and improve physics learning outcomes. One of them is case-based learning. Through this model, students can relate physics concepts to real situations and increase their understanding (Resbiantoro et al., 2022).

Third, reliance on analytical and logical thinking skills when learning physics concepts can be problematic. Students tend to memorise physics formulas without understanding their context or meaning. This causes students to rely solely on analytical skills without understanding how formulas are applied in real situations. When faced with complex problems, students are often unable to relate the memorised formulas to the problems given and they find it difficult to relate physics concepts to everyday experiences. Thus, even though students use analytical skills, their understanding is still shallow (Ricardo, 2016). In general, children use intuition more in understanding natural phenomena or physical phenomena holistically than adults who use more analytical and logical abilities (Bickart, 2024). This is related to children's limited initial knowledge compared to adults. Reduced intuition from childhood to adulthood occurs in physics learning and this is what also makes physics concepts unattractive and difficult for students to understand (Corsiglia et al., 2023). Students often doubt their intuition by preferring more structured and theoretical knowledge. However, in physics, intuition plays an important role in developing theories and understanding complex concepts even though it must be validated through scientific methods (Okoli & Watt, 2018). Furthermore, intuition also depends on how information sources can be presented and understood in physics learning (Ludwin-Peery et al., 2020). When the information provided is limited, students tend to use intuition (Park &

Song, 2020). Consequently, it is vital to understand the importance of intuitive, analytical, and logical thinking in the context of physics education. The three complement each other and can improve students' abilities in solving problems (Park & Song, 2020).

Conclusion

Studies on intuition in physics learning have been conducted at various levels, in different countries, and across various physics topics. Research on intuition in physics learning has been conducted extensively at the university level. Furthermore, physics intuition has been widely applied to kinematics because it relates to everyday life. Beyond synthesizing existing findings, this review contributes a conceptual understanding of intuition as a spontaneous, experience-based, and non-analytical cognitive process that complements analytical thinking. Its spontaneity leads to the emergence of new ideas as part of creative thinking. Thus, intuitive abilities can encourage creativity. Both complement each other by creating innovative and effective solutions to physics problems. Importantly, this study identifies three uses of intuition in learning physics: higher-level thinking, object identification, and cognitive development. It also brings to light an underexplored dimension: the relationship between intuition and mathematical reasoning. Moreover, intuition can be used to address students' difficulty in understanding physics, as intuitive, analytical, and logical thinking complement each other. The originality of this work lies in reframing intuition as a cognitive tool that can enrich physics instruction. As scientific reasoning becomes increasingly essential, integrating intuitive thinking into pedagogical strategies could make physics more accessible, meaningful, and engaging for students. Future studies should explore how instructional designs can be tailored to cultivate intuitive reasoning alongside analytical thinking in diverse classroom settings.

Limitation

The literature reviewed in this SLR is limited to the last 18 years, that is, from 2007 to 2024. This study excludes research published in non-English languages, particularly local and/or regional journals, and focuses exclusively on specific databases that may contain significant insights into intuition in physics education.

Suggestion

The implications for future research from the results of this study include the need for more in-depth research on intuition at every level and other physics topics besides those mentioned and increasing research studies on intuition in several countries, as well as studying learning strategies (models, approaches and methods) to explore the right intuitive abilities. Thus, the results of this study can be a source of information for similar research and provide insights into the importance of intuition in physics learning applied in formal and non-formal settings at all levels. Moreover, the outcomes of this study might provide a preliminary framework for further research that seeks to explicitly include local literature, particularly in non-English languages to cultivate a more inclusive comprehension.

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Declaration of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

- Assem, H. D., Nartey, L., Appiah, E., & Aidoo, J. K. (2023). A review of students' academic performance in physics: Attitude, instructional methods, misconceptions and teachers qualification. *European Journal of Education and Pedagogy*, 4(1), 84–92. <https://doi.org/10.24018/ejedu.2023.4.1.551>
- Baiduri, Y. M. C., & Ulfah, F. (2022). The intuitive thinking process of high ability students in mathematical problem solving based on gender. *Journal of Hunan University Natural Sciences*, 49(2), 1–11. <https://doi.org/10.55463/issn.1674-2974.49.2.1>
- Bancong, H., & Song, J. (2020). Exploring how students construct collaborative thought experiments during physics problem-solving activities. *Science & Education*, 29(3), 617–645. <https://doi.org/10.1007/s11191-020-00129-3>
- Bates, C. J., Yildirim, I., Tenenbaum, J. B., & Battaglia, P. (2019). Modeling human intuitions about liquid flow with particle-based simulation. *PLoS Computational Biology*, 15(7), 1–29. <https://doi.org/10.1371/journal.pcbi.1007210>
- Bickart, J. (2024). The possible role of intuition in education. *Holistic Education Review*, 4(1), 1–19. <https://her.journals.publicknowledgeproject.org/index.php/her/article/view/2812>
- Bouchée, T., de Putter-Smits, L., Thurlings, M., & Pepin, B. (2022). Towards a better understanding of conceptual difficulties in introductory quantum physics courses. *Studies in Science Education*, 58(2), 183–202. <https://doi.org/10.1080/03057267.2021.1963579>
- Brock, R. (2015). Intuition and insight: Two concepts that illuminate the tacit in science education. *Studies in Science Education*, 51(2), 127–167. <https://doi.org/10.1080/03057267.2015.1049843>
- Brown, A., Holtham, C., Rich, M., & Dove, A. (2015). Twenty-first century managers and intuition: An exploratory example of pedagogic change for business undergraduates. *Decision Sciences Journal of Innovative Education*, 13(3), 349–375. <https://doi.org/10.1111/dsji.12066>
- Brunton, G., Oliver, S., & Thomas, J. (2020). Innovations in framework synthesis as a systematic review method. *Research Synthesis Methods*, 11(3), 316–330. <https://doi.org/10.1002/jrsm.1399>
- Burnett, C., & Francisco, J. (2020). Role of intuition in creativity. In *Encyclopedia of creativity, invention, innovation and entrepreneurship* (pp. 2004–2010). Springer.
- Buteler, L. M., & Coleoni, E. A. (2012). Intuitive physics knowledge, physics problem solving and the role of mathematical equations. *Investigações em Ensino de Ciências*, 17(2), 435–452. <https://ienci.if.ufrgs.br/index.php/ienci/article/view/197>
- Buteler, L. M., & Coleoni, E. A. (2014). Exploring the relation between intuitive physics knowledge and equations during problem solving. *Electronic Journal of Science Education*, 18(2), 1–20. <http://ejse.southwestern.edu/article/view/11993>
- Carli, M., Lippiello, S., Pantano, O., Perona, M., & Tormen, G. (2020). Testing students' ability to use derivatives, integrals, and vectors in a purely mathematical context and in a physical context. *Physical Review Physics Education Research*, 16(1), 1–17. <https://doi.org/10.1103/PhysRevPhysEducRes.16.010111>
- Chang, W., & Shieh, R. S. (2013). Exploration of the value of using a formula sheet for physics examinations. *European Journal of Physics*, 34(6), 1411–1422. <https://doi.org/10.1088/0143-0807/34/6/1411>
- Chigbu, U. E., Atiku, S. O., & Du Plessis, C. C. (2023). The science of literature reviews: Searching, identifying, selecting, and synthesising. *Publications*, 11(1), 1–16. <https://doi.org/10.3390/publications11010002>
- Corsiglia, G., Pollock, S., & Passante, G. (2023). Intuition in quantum mechanics: Student perspectives and expectations. *Physical Review Physics Education Research*, 19(1), 1–16. <https://doi.org/10.1103/PhysRevPhysEducRes.19.010109>
- De Toffoli, S. (2021). Reconciling rigor and intuition. *Cognition*, 86, 1783–1802. <https://doi.org/10.1007/s10670-020-00280-x>

- Eshach, H., & Kukliansky, I. (2018). University physics and engineering students' use of intuitive rules, experience, and experimental errors and uncertainties. *International Journal of Science and Mathematics Education, 16*, 817–834. <https://doi.org/10.1007/s10763-017-9817-3>
- Farmaki, V., & Paschos, T. (2007). The interaction between intuitive and formal mathematical thinking: A case study. *International Journal of Mathematical Education in Science and Technology, 38*(3), 353–365. <https://doi.org/10.1080/00207390601035302>
- Fischer, J., & Mahon, B. Z. (2021). What tool representation, intuitive physics, and action have in common: The brain's first-person physics engine. *Cognitive Neuropsychology, 38*(7–8), 455–467. <https://doi.org/10.1080/02643294.2022.2106126>
- Friederich, P., Krenn, M., Tamblyn, I., & Aspuru-Guzik, A. (2021). Scientific intuition inspired by machine learning-generated hypotheses. *Machine Learning: Science and Technology, 2*(2), 1–10. <https://doi.org/10.1088/2632-2153/abda08>
- Gette, C. R., & Kryjevskaja, M. (2019). Establishing a relationship between student cognitive reflection skills and performance on physics questions that elicit strong intuitive responses. *Physical Review Physics Education Research, 15*(1), 1–13. <https://doi.org/10.1103/PhysRevPhysEducRes.15.010118>
- Gisin, N. (2021). Indeterminism in physics and intuitionistic mathematics. *Synthesis, 199*(5), 13345–13371. <https://doi.org/10.1007/s11229-021-03378-z>
- Grehl, S., & Tutić, A. (2022). Intuition, reflection, and prosociality: Evidence from a field experiment. *PLOS ONE, 17*(2), 1–14. <https://doi.org/10.1371/journal.pone.0262476>
- Grève, S. (2023). Intuitive skill. *Philosophia, 51*(3), 1677–1700. <https://doi.org/10.1007/s11406-023-00627-y>
- Hannousse, A., & Yahiouche, S. (2021). Securing microservices and microservice architectures: A systematic mapping study. *Computer Science Review, 41*, 1–16. <https://doi.org/10.1016/j.cosrev.2021.100415>
- Isenman, L. (2018). *Understanding intuition: A journey in and out of science*. Academic Press.
- Ismail, N., & Yusof, U. K. (2023). A systematic literature review: Recent techniques of predicting STEM stream students. *Computers and Education: Artificial Intelligence, 5*, 1–23. <https://doi.org/10.1016/j.caeai.2023.100141>
- Julmi, C. (2024). Analysis and intuition effectiveness in moral problems. *Journal of Business Ethics, 191*, 179–193. <https://doi.org/10.1007/s10551-023-05407-y>
- Kalajian, P., & Makarova, M. (2014). Friction and the intuition-outcome disparity. *The Physics Teacher, 52*(3), 172–173. <https://doi.org/10.1119/1.4865523>
- Kapodistrias, A., & Airey, J. (2024). Rearranging equations to develop physics reasoning. *European Journal of Physics, 45*(3), 1–21. <https://doi.org/10.1088/1361-6404/ad261c>
- Kirkeboen, G., & Nordbye, G. H. (2017). Intuitive choices lead to intensified positive emotions: An overlooked reason for “intuition bias”? *Frontiers in Psychology, 8*(1942), 1–11. <https://doi.org/10.3389/fpsyg.2017.01942>
- Koerfer, E., & Ye, S. (2024). Managing intuition in collaborative problem solving: A case study of beyond-intro physics and chemistry students. In *2024 Physics Education Research Conference Proceedings* (pp. 218–223). Uppsala University. <https://doi.org/10.1119/perc.2024.pr.Koerfer>
- Körhasan, N. D., & Gürel, D. K. (2019). Student teachers' physics knowledge and sources of knowledge to explain everyday phenomena. *Science Education International, 30*(4), 298–309. <https://doi.org/10.33828/sei.v30.i4.7>
- Korherr, P., Kanbach, D. K., Kraus, S., & Jones, P. (2023). The role of management in fostering analytics: The shift from intuition to analytics-based decision-making. *Journal of Decision Systems, 32*(3), 600–616. <https://doi.org/10.1080/12460125.2022.2062848>
- Król, Z. (2020). The intuitive concept of information: An analysis. *Studies in Logic, Grammar and Rhetoric, 63*(1), 101–119. <https://doi.org/10.2478/slgr-2020-0030>
- Kryjevskaja, M., Stetzer, M. R., & Grosz, N. (2014). Answer first: Applying the heuristic-analytic theory of reasoning to examine student intuitive thinking in the context of physics. *Physical*

- Review Special Topics - Physics Education Research*, 10(2), 1–12.
<https://doi.org/10.1103/PhysRevSTPER.10.020109>
- Kubricht, J. R., Holyoak, K. J., & Lu, H. (2017). Intuitive physics: Current research and controversies. *Trends in Cognitive Sciences*, 21(10), 749–759. <https://doi.org/10.1016/j.tics.2017.06.002>
- Kulgemeyer, C., & Wittwer, J. (2023). Misconceptions in physics explainer videos and the illusion of understanding: An experimental study. *International Journal of Science and Mathematics Education*, 21(2), 417–437. <https://doi.org/10.1007/s10763-022-10265-7>
- Lemmer, M. (2013). Nature, cause and effect of students' intuitive conceptions regarding changes in velocity. *International Journal of Science Education*, 35(2), 239–261. <https://doi.org/10.1080/09500693.2011.647110>
- Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P., & Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and elaboration. *Annals of Internal Medicine*, 151(4), 65–94. <https://doi.org/10.7326/0003-4819-151-4-200908180-00136>
- Longo, G., & Viarouge, A. (2010). Mathematical intuition and the cognitive roots of mathematical concepts. *Topoi*, 29, 15–27. <https://doi.org/10.1007/s11245-009-9063-6>
- Ludwin-Peery, E., Bramley, N. R., Davis, E., & Gureckis, T. M. (2020). Broken physics: A conjunction-fallacy effect in intuitive physical reasoning. *Psychological Science*, 31(12), 1602–1611. <https://doi.org/10.1177/0956797620957610>
- Ludwin-Peery, E., Bramley, N. R., Davis, E., & Gureckis, T. M. (2021). Limits on simulation approaches in intuitive physics. *Cognitive Psychology*, 127, 1–25. <https://doi.org/10.1016/j.cogpsych.2021.101396>
- Malaspina, U., & Font, V. (2010). The role of intuition in the solving of optimization problems. *Educational Studies in Mathematics*, 75, 107–130. <https://doi.org/10.1007/s10649-010-9243-8>
- Masin, S. C., Crivellaro, F., & Varotto, D. (2014). The intuitive physics of the equilibrium of the lever and of the hydraulic pressures: Implications for the teaching of elementary physics. *Psicologica*, 35(3), 441–461.
- Mayer, C. H., & Maree, D. (2017). A psychobiographical study of intuition in a writer's life: Paulo Coelho revisited. *Europe's Journal of Psychology*, 13(3), 472–490. <https://doi.org/10.5964/ejop.v13i3.1184>
- Mbwile, B., & Hegwa, P. J. (2025). Pre-service physics teachers' conceptual understanding of kinematics graphs in Tanzania. *Journal of Turkish Science Education*, 22(2), 354–373. <https://doi.org/10.36681/tused.2025.018>
- McCoy, J., & Ullman, T. (2019). Judgments of effort for magical violations of intuitive physics. *PLOS ONE*, 14(5), 1–11. <https://doi.org/10.1371/journal.pone.0217513>
- Miller, H. E. (2018). Intuition and decision making for crisis situations. In *The Routledge companion to risk, crisis and security in business* (pp. 47–61). Routledge. <https://doi.org/10.4324/9781315629520-3>
- Mitko, A., Navarro-Cebrián, A., Cormiea, S., & Fischer, J. (2024). A dedicated mental resource for intuitive physics. *iScience*, 27(1), 1–19. <https://doi.org/10.1016/j.isci.2023.108607>
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & Prisma Group. (2010). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *International Journal of Surgery*, 8(5), 336–341. <https://doi.org/10.1016/j.ijssu.2010.02.007>
- Monsay, E. H. (2016). Intuition in the development of scientific theory and practice. In *Intuition: The inside story* (pp. 103–120). Routledge.
- Müller, R. M., Herziger, B., Jeschke, S., Neining, M. P., Bertsche, T., & Bertsche, A. (2024). How intuitive is the administration of pediatric emergency medication devices for parents? Objective observation and subjective self-assessment. *Pharmacy*, 12(1), 1–12. <https://doi.org/10.3390/pharmacy12010036>

- Neupärthl, N., Tatai, F., & Rothkopf, C. A. (2020). Intuitive physical reasoning about objects' masses transfers to a visuomotor decision task consistent with Newtonian physics. *PLoS Computational Biology*, *16*(10), 1–26. <https://doi.org/10.1371/journal.pcbi.1007730>
- Okoli, J., & Watt, J. (2018). Crisis decision-making: The overlap between intuitive and analytical strategies. *Management Decision*, *56*(5), 1122–1134. <https://doi.org/10.1108/MD-04-2017-0333>
- Oral, I., & Erkilic, M. (2022). Investigating the 21st-century skills of undergraduate students: Physics success, attitude, and perception. *Journal of Turkish Science Education*, *19*(1), 284–301. <https://doi.org/10.36681/tused.2022.122>
- Ospanbekov, Y., Maxutov, S., Sandybayev, Y., Boranbekova, A., & Balta, N. (2024). Peer instruction's Achilles' heel: An analysis of its ineffectiveness in confronting counterintuitive physics questions. *EURASIA Journal of Mathematics, Science and Technology Education*, *20*(8), 1–13. <https://doi.org/10.29333/ejmste/14778>
- Palmgren, E., & Rasa, T. (2024). Modelling roles of mathematics in physics: Perspectives for physics education. *Science & Education*, *33*(2), 365–382. <https://doi.org/10.1007/s11191-022-00393-5>
- Park, J., & Song, J. (2020). How is intuitive thinking shared and elaborated during small-group problem-solving activities on thermal phenomena? *Research in Science Education*, *50*(6), 2363–2390. <https://doi.org/10.1007/s11165-018-9784-x>
- Pétervári, J., Osman, M., & Bhattacharya, J. (2016). The role of intuition in the generation and evaluation stages of creativity. *Frontiers in Psychology*, *7*(1420), 1–12. <https://doi.org/10.3389/fpsyg.2016.01420>
- Piloto, L. S., Weinstein, A., Battaglia, P., & Botvinick, M. (2022). Intuitive physics learning in a deep-learning model inspired by developmental psychology. *Nature Human Behaviour*, *6*(9), 1257–1267. <https://doi.org/10.1038/s41562-022-01394-8>
- Polcyn, K. (2023). Does the intuition of distinctness result from valid reasoning?—Reply to Kammerer. *Review of Philosophy and Psychology*, *14*(1), 321–337. <https://doi.org/10.1007/s13164-021-00592-z>
- Popova, Y., Abdualiyeva, M., Torebek, Y., Yelshibekov, N., & Omashova, G. (2022). Improving the effectiveness of senior graders' education based on the development of mathematical intuition and logic: Kazakhstan's experience. *Frontiers in Education*, *7*, 1–13. <https://doi.org/10.3389/educ.2022.986093>
- Rahmah, N., Darsikin, D., Kade, A., & Muslimin, M. (2020). The models of physical intuition students use phenomenological elements in solving physics problems. *Journal of Physics Education*, *8*(2), 163–176. <https://doi.org/10.26618/jpf.v8i2.3352>
- Resbiantoro, G., Setiani, R., & Dwikoranto. (2022). A review of misconception in physics: The diagnosis, causes, and remediation. *Journal of Turkish Science Education*, *19*(2), 403–427. <https://doi.org/10.36681/>
- Ricardo, B. (2016). Comprehensive analysis of the failure of intuition in elementary rigid body dynamics. *Applied Physics Research*, *8*(1), 125–137. <https://doi.org/10.5539/apr.v8n1p125>
- Sahlfeld, W. (2018). Méthode intuitive: Interregional and international circulation of a pedagogical idea (end of 19th century). *Journal of History of Education*, *5*(2), 59–72. <https://rivistadistoriadelleducazione.it/index.php/rse/article/view/7621>
- Sakho, I. (2019). *Introduction to quantum mechanics 1: Thermal radiation and experimental facts regarding the quantization of matter*. John Wiley & Sons.
- Sanborn, A. N., Mansinghka, V. K., & Griffiths, T. L. (2013). Reconciling intuitive physics and Newtonian mechanics for colliding objects. *Psychological Review*, *120*(2), 411–437. <https://doi.org/10.1037/a0031912>
- Seo, J., & Lee, S. W. (2021). Neural network-based intuitive physics for non-inertial reference frames. *IEEE Access*, *9*, 114246–114254. <https://doi.org/10.1109/ACCESS.2021.3103876>
- Sherrin, B. L. (2006). Common sense clarified: The role of intuitive knowledge in physics problem solving. *Journal of Research in Science Teaching*, *43*(6), 535–555. <https://doi.org/10.1002/tea.20136>
- Shtulman, A. (2014). Science v. intuition: Why it is difficult for scientific knowledge to take root. *Skeptic*, *19*(3), 46–51.

- Shtulman, A., & Young, A. G. (2024). Tempering the tension between science and intuition. *Cognition*, 243. <https://doi.org/10.1016/j.cognition.2023.105680>
- Siddaway, A. P., Wood, A. M., & Hedges, L. V. (2019). How to do a systematic review: A best practice guide for conducting and reporting narrative reviews, meta-analyses, and meta-syntheses. *Annual Review of Psychology*, 70(1), 747–770. <https://doi.org/10.1146/annurev-psych-010418-102803>
- Sinclair, M. (2010). Misconceptions about intuition. *Psychological Inquiry*, 21(4), 378–386. <https://doi.org/10.1080/1047840X.2010.523874>
- Sipman, G., Martens, R., Thölke, J., & McKenney, S. (2024). Exploring teacher awareness of intuition and how it affects classroom practices: Conceptual and pragmatic dimensions. *Professional Development in Education*, 50(4), 746–759. <https://doi.org/10.1080/19415257.2021.1902839>
- Smith, K. A., Battaglia, P. W., & Vul, E. (2018). Different physical intuitions exist between tasks, not domains. *Computational Brain & Behavior*, 1, 101–118. <https://doi.org/10.1007/s42113-018-0007-3>
- Sosa, F. A., Ullman, T., Tenenbaum, J. B., Gershman, S. J., & Gerstenberg, T. (2021). Moral dynamics: Grounding moral judgment in intuitive physics and intuitive psychology. *Cognition*, 217, 1–20. <https://doi.org/10.1016/j.cognition.2021.104890>
- Suwarto, S., Hidayah, I., Rochmad, R., & Masrukan, M. (2023). Intuitive thinking: Perspectives on intuitive thinking processes in mathematical problem solving through a literature review. *Cogent Education*, 10(2), 1–14. <https://doi.org/10.1080/2331186X.2023.2243119>
- Tallant, J. (2013). Intuitions in physics. *Synthesis*, 190(15), 2959–2980. <https://doi.org/10.1007/s11229-012-0113-z>
- Tallant, J. (2015). Metaphysics, intuitions and physics. *Ratio*, 28(3), 286–301. <https://doi.org/10.1111/rati.12074>
- Vicovaro, M. (2014). Intuitive physics of free fall: An information integration approach to the mass-speed belief. *Psicológica*, 35(3), 463–477. <https://hdl.handle.net/11577/3023099>
- Vicovaro, M. (2018). Causal reports: Context-dependent contributions of intuitive physics and visual impressions of launching. *Acta Psychologica*, 186, 133–144. <https://doi.org/10.1016/j.actpsy.2018.04.015>
- Vicovaro, M. (2021). Intuitive physics and cognitive algebra: A review. *European Review of Applied Psychology*, 71(5), 1–19. <https://doi.org/10.1016/j.erap.2020.100610>
- Vicovaro, M. (2023). Grounding intuitive physics in perceptual experience. *Journal of Intelligence*, 11(10), 1–20. <https://doi.org/10.3390/jintelligence11100187>
- Vicovaro, M., & Burigana, L. (2016). Intuitive understanding of the relationship between the elasticity of objects and kinematic patterns of collisions. *Attention, Perception, & Psychophysics*, 78, 618–635. <https://doi.org/10.3758/s13414-015-1033-z>
- Villoro, I. A. J., & Estaun, I. F. S. (2018). May schools develop their students' intuition? *Multidisciplinary Journal for Education, Social and Technological Science*, 5(2), 19–49. <https://doi.org/10.4995/muse.2018.9958>
- Welch, I. V., Navakas, F., & Fiscella, J. (2007). The role of intuition in interdisciplinary insight. *Issues in Interdisciplinary Studies*, 25, 131–155.
- Wittmann, M. C., & Morgan, J. T. (2020). Foregrounding epistemology and everyday intuitions in a quantum physics course for nonscience majors. *Physical Review Physics Education Research*, 16(2), 1–16. <https://doi.org/10.1103/PhysRevPhysEducRes.16.020159>
- Wong, K. W., Bi, W., Soltani, A. A., Yildirim, I., & Scholl, B. J. (2023). Seeing soft materials draped over objects: A case study of intuitive physics in perception, attention, and memory. *Psychological Science*, 34(1), 111–119. <https://doi.org/10.1177/09567976221109194>
- Wu, H., Gong, W., & Yi, G. (2024). Exploration of the relationships among epistemic views of physics, conceptions of learning physics, and approaches to learning physics for college engineering students. *Science & Education*, 33(3), 699–715. <https://doi.org/10.1007/s11191-022-00385-5>

- Yavuz, A. (2015). Do students trust in mathematics or intuition during physics problem solving? An epistemic game perspective. *EURASIA Journal of Mathematics, Science and Technology Education*, 11(3), 633–646. <https://doi.org/10.12973/eurasia.2014.1205a>
- Zhang, Z., Lei, Y., & Li, H. (2016). Approaching the distinction between intuition and insight. *Frontiers in Psychology*, 7(1195), 1–5. <https://doi.org/10.3389/fpsyg.2016.01195>