Jurnal Cakrawala Pendas
Vol. 12 No. 2, April 2026
DOI: http://dx.doi.org/10.31949/jcp.v12i2.17554

p-ISSN: 2442-7470
e-ISSN: 2579-4442

EXAMINING GENDER DIFFERENCES IN STUDENTS' CONCEPTUAL CHANGE THROUGH RADEC MODEL ASSISTED BY VIRTUAL LABORATORY

Henni Riyanti[1], Wahyu Sopiandi[2*], Dadi Mulyadi[3], Muslim[4]
[1,2,3,4] Education University of Indonesia, Bandung, Indonesia
[2] wsopandi@upi.edu

Abstract

Conceptual change is a fundamental goal of science learning, particularly in elementary teacher education, where preservice teachers' understanding of scientific concepts directly influences their future instructional practices. This study aimed to examine the relationship between gender and students' conceptual change in science learning implemented through the RADEC (Read–Answer–Discuss–Explain–Create) learning model assisted by a virtual laboratory. A correlational research design was employed involving first-semester students of the Elementary School Teacher Education (PGSD) program at a private university in South Sumatra. Data were collected using a four-tier conceptual change test on magnetism concepts. The sample comprised 39 students selected through random sampling, including 34 female and 5 male students. Students' conceptual change was analyzed using normalized gain (N-gain), while the relationship between gender and conceptual change was examined using Pearson correlation analysis with SPSS version 26. The results indicated a statistically significant relationship between gender and students' conceptual change in the implementation of the RADEC model assisted by a virtual laboratory ($r = 0.190$, $p < 0.05$). However, the strength of the correlation is weak, indicating that gender is not a major determinant of students' conceptual development. Future research is recommended to explore additional factors influencing conceptual change, including prior knowledge, learning motivation, and student engagement, to better understand the determinants of students' conceptual development.
Keywords: *Elementary Teacher Education; Conceptual Change; Gender; RADEC; Virtual Laboratory*

Abstrak

Perubahan konseptual merupakan tujuan fundamental dalam pembelajaran sains, khususnya pada PGSD, karena pemahaman konseptual mahasiswa calon guru terhadap konsep akan secara langsung memengaruhi praktik pembelajaran selanjutnya. Penelitian ini bertujuan untuk mengkaji hubungan antara gender dan perubahan konseptual mahasiswa yang diterapkan melalui model RADEC (Read–Answer–Discuss–Explain–Create) berbantuan laboratorium virtual. Penelitian ini menggunakan desain penelitian korelasional yang melibatkan mahasiswa semester pertama Program Studi Pendidikan Guru Sekolah Dasar (PGSD) di salah satu perguruan tinggi swasta di Sumatera Selatan. Pengumpulan data dilakukan menggunakan tes perubahan konseptual berbentuk four-tier test pada materi kemagnetan. Sampel penelitian berjumlah 39 mahasiswa yang dipilih melalui teknik random sampling, terdiri atas 34 mahasiswa perempuan dan 5 mahasiswa laki-laki. Perubahan konseptual mahasiswa dianalisis menggunakan nilai N-gain, sedangkan hubungan antara gender dan perubahan konseptual dianalisis menggunakan uji korelasi Pearson dengan bantuan perangkat lunak SPSS versi 26. Hasil penelitian menunjukkan adanya hubungan yang signifikan secara statistik antara gender dan perubahan konsepsi mahasiswa dalam penerapan model RADEC berbantuan laboratorium virtual ($r = 0{,}190$, $p < 0{,}05$). Namun demikian, kekuatan korelasi tersebut tergolong lemah, yang mengindikasikan bahwa gender bukan merupakan faktor utama yang menentukan perkembangan konseptual mahasiswa. Penelitian selanjutnya direkomendasikan untuk mengeksplorasi faktor-faktor lain yang memengaruhi perubahan konsepsi, termasuk pengetahuan awal, motivasi belajar, dan keterlibatan mahasiswa, guna memperoleh pemahaman yang lebih komprehensif mengenai faktor-faktor yang menentukan perkembangan konseptual mahasiswa.
Kata Kunci: Pendidikan Guru Sekolah Dasar; Perubahan Konsepsi; Gender; RADEC; Laboratorium Virtual

Received	: 2026-02-03	Approved	: 2026-04-20
Reviesed	: 2026-04-19	Published	: 2026-04-30

Introduction

Conceptual understanding is a central foundation of effective science learning, particularly for Elementary Teacher Education students who will become future elementary school teachers, because it enables learners to organize scientific knowledge into coherent frameworks that support reasoning, problem solving, and transfer to new contexts rather than relying on rote memorization (Bransford et al., 2001). Li, et al., (2021) also said that research in science education consistently shows that deep conceptual understanding is essential for overcoming persistent misconceptions, which often remain resistant to traditional, lecture-based instruction and can be unintentionally transmitted from teachers to students when not properly addressed during preservice education. Empirical studies in PGSD contexts demonstrate that instructional approaches grounded in conceptual change, such as Conceptual Change Text (CCT) and inquiry-based learning, significantly improve students' conceptual mastery and learning gains compared to conventional methods, highlighting the importance of engaging students in cognitive conflict and reflective reconstruction of ideas (Sukmawati et al., 2022). Furthermore, strong conceptual understanding among PGSD students is closely linked to their pedagogical competence, as it equips them to design meaningful science lessons, anticipate student misconceptions, and facilitate inquiry-oriented learning that promotes scientific literacy at the elementary level (Pratiwi et al., 2023). Therefore, strengthening conceptual understanding in science courses within PGSD programs is not only critical for improving preservice teachers' academic achievement but also for ensuring the quality and effectiveness of science instruction delivered to future generations of learners.

Students' conceptual difficulties in magnetism are largely shaped by robust prior conceptions that originate from everyday experiences and intuitive reasoning, which often conflict with formal scientific explanations. Recent studies in physics education research reveal that students frequently interpret magnetic interactions through object-based and force-centric reasoning, such as assuming magnetic forces act only through direct contact or believing that magnetism is confined to visible poles rather than distributed through a magnetic field (Planinić et al., 2019). Empirical evidence further by Guisasola et al. (2020) indicates that learners struggle to conceptualize magnetic fields as abstract entities, often confusing field strength with force or current and failing to recognize the superposition and spatial nature of magnetic fields. These difficulties persist across secondary and tertiary levels, suggesting that conventional instruction emphasizing formulas and problem-solving procedures does not sufficiently address students' underlying mental models (Zuza et al., 2021). From a constructivist and conceptual change perspective, students assimilate new magnetic concepts into pre-existing frameworks unless instruction explicitly elicits and challenges their prior knowledge through inquiry-based tasks, multiple representations, and guided reasoning (Duit & Treagust, 2019). Consequently, effective magnetism instruction must prioritize conceptual coherence and cognitive conflict to facilitate meaningful restructuring of students' prior conceptions into scientifically accurate understandings.

Conceptual change has become a central objective in contemporary science education because meaningful learning requires learners to reorganize deeply held prior conceptions rather than merely accumulate new factual knowledge. Extensive research demonstrates that students enter science classrooms with intuitive, experience-based conceptions that often conflict with scientific explanations and remain resistant to traditional instruction focused on transmission of information (Duit & Treagust, 2019). Recent conceptual change frameworks emphasize that learning is a dynamic process involving cognitive, metacognitive, and motivational dimensions, where students must recognize the limitations of their existing ideas and actively engage in restructuring their conceptual frameworks (Vosniadou, 2020). Empirical studies further by Linn, et al. (2018) and Sinatra, et al. (2022) indicate that instructional approaches promoting conceptual change—such as inquiry-based learning, cognitive conflict, multiple representations, and argumentation—are more effective in fostering durable understanding and transfer of knowledge than rote learning strategies Moreover, conceptual change is increasingly viewed as essential for developing scientific literacy, as it enables learners to apply core concepts flexibly across contexts and reason scientifically about real-world phenomena (Treagust & Duit, 2023). Therefore, positioning conceptual change as a primary instructional goal is critical for advancing deep understanding and addressing persistent misconceptions in science education.

Gender differences in conceptual change in science learning have been increasingly examined through cognitive, motivational, and sociocultural perspectives, revealing nuanced patterns rather than consistent performance gaps. Recent research indicates that while male and female students often enter science classrooms with comparable levels of prior misconceptions, they may differ in how they engage with instructional conditions designed to promote conceptual change (Sinatra et al., 2018). Studies suggest that female students tend to benefit more from learning environments emphasizing collaboration, reflection, and epistemic dialogue, which support metacognitive regulation and conceptual restructuring, whereas male students may show stronger gains in highly competitive or task-oriented settings (Ceci et al., 2019). Moreover, motivational factors such as science self-efficacy, interest, and epistemic beliefs have been found to mediate gender-related differences in conceptual change, with female students sometimes exhibiting deeper conceptual revision when instruction explicitly supports confidence and relevance (Lombardi et al., 2021). Importantly, large-scale and classroom-based studies demonstrate that when inquiry-based and conceptual change-oriented pedagogies are equitably implemented, gender differences in learning outcomes tend to diminish, underscoring that observed disparities are largely contextual rather than inherent (Mujtaba & Reiss, 2020). Therefore, understanding gender differences in conceptual change requires moving beyond binary comparisons toward designing inclusive instructional strategies that address diverse cognitive and motivational needs in science learning.

The RADEC (Read-Answer-Discuss-Explain-Create) learning model, increasingly implemented in elementary and secondary science education, has demonstrated effectiveness in fostering conceptual understanding, active engagement, and higher-order thinking when supported by virtual or digital laboratory-like environments; research indicates that the RADEC model's structured cognitive phases inherently promote learner participation in constructing scientific knowledge, and when paired with digital learning technologies, such as interactive games, augmented reality (AR), or other virtual/digital tools, students exhibit significant gains in mastery of science concepts, motivation, and critical thinking compared with conventional methods (Alimuddin et al., 2024; Kirana et al., 2025). For example, RADEC assisted by interactive game elements showed marked improvement in basic science concept mastery among prospective elementary teachers, indicating that digital augmentation can enhance engagement and deepen conceptual processing (Alimuddin et al., 2024). Similarly, the integration of RADEC with AR-based digital materials for human digestive system instruction illustrates how virtual laboratory features, visual simulations, interactive 3D views, and scaffolded tasks, can support students' active exploration and explanation phases, leading to better participation and conceptual coherence (Kirana et al., 2025). Additionally, more traditional applications of RADEC in thematic science instruction reveal that even without fully immersive virtual labs, the model's design encourages students to explain and create based on inquiry, aligning with virtual lab principles of exploration, hypothesis testing, and feedback cycles, which are hallmarks of effective science learning in digital contexts. Collectively, these studies reinforce that RADEC assisted by virtual or digital laboratory-like innovations can drive deeper science learning outcomes, making it a promising pedagogical approach for 21st-century science education.

Despite increasing interest in gender differences in science education, research specifically investigating gender-based conceptual change among elementary teacher education students remains limited. Most existing studies on gender differences in science learning focus on achievement, interest, or general misconceptions (e.g., science process skills or conceptual understanding broadly) rather than on how gender influences the process of conceptual change, the restructuring of pre-existing science ideas into scientifically accepted concepts, particularly among future educators who must not only learn but also teach scientific concepts effectively. Current evidence by Cahyanto, et al. (2019) and Lin & Wong (2024) demonstrates that gender can relate to different patterns in science learning outcomes (e.g., conceptual understanding, engagement, and interest), but few studies have systematically examined whether male and female teacher candidates differentially experience conceptual change processes during instruction or how these differences might affect their future teaching practices. Moreover, the interaction between gender, prior knowledge, motivational factors, and instructional strategies that specifically target conceptual change has not been fully explored, leaving a gap in understanding whether gender moderates responses to conceptual change pedagogy in teacher education contexts. This gap is significant because elementary teacher education students are a critical population: their conceptual frameworks and ability to negotiate change will influence how they detect and address misconceptions in their future students. Therefore, more focused, gender-responsive research is needed that assesses both how and why male and female teacher candidates differ in their conceptual change trajectories, as well as what instructional structures support equitable conceptual development for all genders in science education preparation programs.

Investigating gender differences in conceptual change within science learning is urgent because gender can influence how students engage with, process, and integrate scientific concepts, which in turn affects long-term understanding, participation in STEM, and professional preparation, especially for those who will become educators themselves. Research shows that gender may shape motivational and cognitive factors such as interest, self-efficacy, engagement, and potentially the ways learners interact with conceptual change instructional approaches, yet systematic inquiry into these differences, particularly in the context of conceptual change pedagogy, remains sparse (Lin & Wong, 2024). Understanding gender differences is essential to ensure that instructional strategies designed to promote conceptual restructuring, such as inquiry-based learning or cognitive conflict tasks, do not inadvertently favor one gender over another or reinforce existing inequities in science learning outcomes. Furthermore, as conceptual change is fundamental to overcoming persistent misconceptions and building scientific literacy, failing to account for gender-based differences may lead to inequitable science education practices that disadvantage either male or female learners. This urgency is heightened in elementary teacher education because future teachers' conceptual foundations will influence their instructional decisions and their ability to foster equitable science understanding in diverse classrooms. Thus, targeted research on gender differences in conceptual change can inform more inclusive teacher preparation frameworks that promote deep conceptual understanding for all future educators.

Research Methods

This study employed a correlational research design to investigate the relationship between gender and students' conceptual change in science learning, without any manipulation of the research variables. The purpose of this design was to identify the degree and direction of association between gender and changes in students' scientific conceptions.

The research population included all first-semester students enrolled in the Elementary School Teacher Education (PGSD) program at a private university in South Sumatra, Indonesia, with a total population of 600 students. A sample of 39 students was selected using a random sampling technique to ensure that each member of the population had an equal chance of participation. The sample consisted of 34 female students and 5 male students.

Data were collected using a conceptual change test developed in the form of a four-tier diagnostic instrument, which is designed to assess not only students' answers but also their reasoning and level of confidence. The instrument consisted of 12 items, comprising 6 pretest items administered prior to instruction and 6 posttest items administered after instruction, in order to measure shifts in students' conceptions over time.

The research design consisted of three stages: a pretest on magnetism, instruction using the RADEC learning model assisted by a Virtual Laboratory, and a posttest on magnetism. Students' conceptual change were collected using four-tier test and analyzed using the normalized gain (N-gain, $\langle g \rangle$). Students' conceptual change was classified into three categories: High (if $\langle g \rangle > 0.7$), Moderate (if $0.3 \leq \langle g \rangle \leq 0.7$), and Low (if $\langle g \rangle < 0.3$).

Data analysis was conducted using descriptive quantitative methods with the assistance of SPSS version 22. Pearson correlation analysis was employed to examine the relationship between gender and students' conceptual change, providing statistical evidence of the strength and direction of the association between the variables

Result and Discussion

The pretest and posttest data on students' conceptual change were collected and analyzed using the normalized gain (N-gain, $\langle g \rangle$). Students' conceptual change was classified into three categories: High (if $\langle g \rangle > 0.7$), Moderate (if $0.3 \leq \langle g \rangle \leq 0.7$), and Low (if $\langle g \rangle < 0.3$). The data on conceptual change between male and female students are presented in Table 1 and Figure 1.

Table 1. Students' conceptual change based on gender

No	Category	Female		Male	
		f	%	f	%
1	High	15	44%	1	20%
2	Moderate	15	44%	4	80%
3	Low	4	12%	0	0%

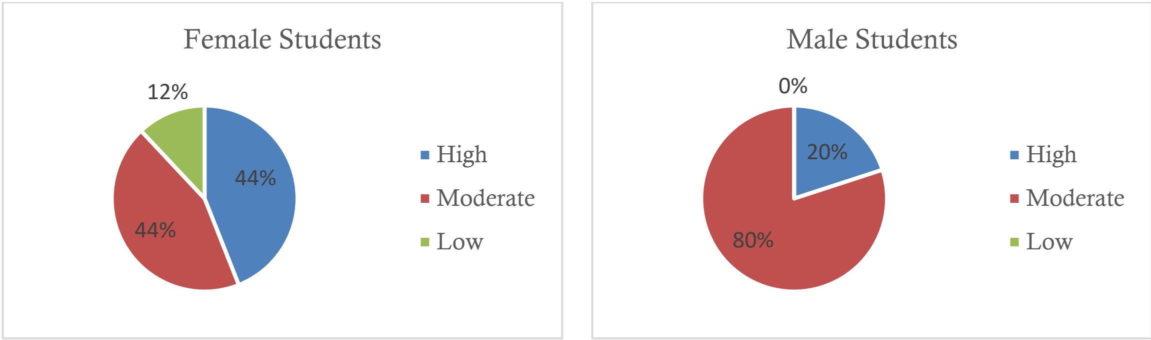

Figure1. The distribution of students' conceptual change

Based on Table 1 and Figure 1, it is found that among female students, the highest percentages of conceptual change are in the highand moderate categories, each accounting for 44%. Meanwhile, among male students, the largest percentage of conceptual change is in the moderate category, amounting to 80%.

This study examined the relationship between students' conceptual change and gender by applying Pearson correlation analysis using SPSS version 22, with a significance level set at $\alpha = 0.05$. The results of the analysis presented in Table 2.

Table 2. The relationship between students' conceptual change and gender

		Gender	**Values**
Gender	Pearson Correlation	1	0.19
	Sign. (2-tailed)		0.02
	N	39	39
Students' conceptual change	Pearson Correlation	0.19	1
	Sign. (2-tailed)	0.02	
	N	39	39

Based on Table 2, The results of the Pearson correlation analysis revealed a statistically significant relationship between gender and students' conceptual change ($r = 0.190$, $p = 0.02 < 0.05$). This indicates that gender is associated with students' conceptual development in RADEC model learning assisted by a virtual laboratory. However, the correlation coefficient suggests that the relationship is weak, meaning that gender is not the primary factor influencing conceptual change.

This finding is consistent with previous studies indicating that gender can influence cognitive outcomes, although its effect is often limited. For instance, a study on RADEC learning reported that gender differences affected students' critical thinking skills, with female students achieving slightly higher outcomes than male students (Setiawan et al., 2024). This supports the notion that gender may contribute to differences in learning outcomes, but not necessarily as a dominant determinant.

The weak correlation found in this study may be explained by the nature of the RADEC model itself. The RADEC model is grounded in constructivist theory, emphasizing active learning through reading, answering, discussing, explaining, and creating. These stages promote student engagement, social interaction, and knowledge construction, which are essential for conceptual understanding. Because constructivist learning environments tend to involve all learners actively, they can reduce disparities between male and female students (Pahlevi, 2025).

In addition, the integration of virtual laboratories likely contributed to minimizing gender differences. Virtual laboratories provide interactive simulations that allow students to explore concepts independently and at their own pace. Research shows that virtual labs can create a constructivist learning environment and enhance student engagement and understanding (Tawil et al., 2024; Widodo et al., 2017). Such environments can help overcome traditional barriers in science learning, including differences in confidence, prior experience, or participation often associated with gender.

Furthermore, recent research on RADEC integrated with virtual laboratories confirms its effectiveness in promoting conceptual change and supporting student-centered learning. This suggests that the instructional design itself plays a more significant role than gender in influencing conceptual understanding. Despite the statistical significance, the low correlation coefficient indicates that other factors likely have a stronger impact on students' conceptual change. These factors may include prior knowledge, learning motivation, level of participation during RADEC stages, and digital literacy. Previous studies also highlight that student characteristics and learning environments interact in complex ways, and gender is only one of many influencing variables.

Moreover, it is important to distinguish between statistical and practical significance. A significant p-value ($p < 0.05$) does not necessarily imply a strong or meaningful effect in practice. In this case, the small correlation ($r = 0.190$) suggests that the practical influence of gender is limited. Overall, this study demonstrates that while gender has a statistically significant relationship with students' conceptual change, its influence is relatively weak. The RADEC model assisted by virtual laboratories appears to promote a more inclusive and equitable learning environment, reducing gender disparities. Future research should explore other variables that may have stronger effects on conceptual change and examine how instructional design can further enhance equity in science learning.

Conclusion

This study concludes that there is a statistically significant relationship between gender and students' conceptual change in the implementation of the RADEC model assisted by a virtual laboratory ($r = 0.190$, $p < 0.05$). However, the strength of the correlation is weak, indicating that gender is not a major determinant of students' conceptual development. The findings suggest that the RADEC model, supported by virtual laboratory environments, is effective in promoting conceptual change in an inclusive manner, providing relatively equal learning opportunities for both male and female students. The constructivist nature of the RADEC stages encourages active participation and knowledge construction, which may reduce gender disparities in learning outcomes. Despite the significant relationship, the limited magnitude of the correlation highlights that other factors likely play a more substantial role in influencing conceptual change. Therefore, gender should be considered as only one of many contributing variables rather than a primary influencing factor. In conclusion, this study emphasizes the importance of instructional design in fostering equitable learning outcomes. Future research is recommended to explore additional variables affecting conceptual change and to further examine how innovative learning models can enhance both effectiveness and equity in science education.

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