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Research Article

Anthropocentric Reasoning of Weight, Friction, Buoyancy, and Air Resistance among Pre-Service Teachers

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Abstract: This study examines anthropocentric misunderstandings among pre-service educators concerning the forces of weight, friction, buoyancy, and air resistance. A total of 476 first-year students in a Greek Primary Education Department completed an open-ended questionnaire regarding the origins of these forces. Qualitative content analysis categorized responses into six classifications: scientifically accurate explanation, medium-based attribution, anthropocentric reasoning, erroneous application of Newton's third law, mathematical equation, and other/no response. The majority of participants provided precise explanations for weight and friction; however, less than one-third did so for buoyancy and fewer than one-fifth for air resistance. Approximately 18% provided at least one anthropocentric explanation, such as "friction exists to prevent slipping" or "air resistance facilitates parachuting," with a minor subgroup employing this rationale for all four forces. These findings indicate that purpose-driven, human-centered explanations endure despite recent university instruction, suggesting fragmented mental models. The findings highlight the necessity for teacher education programs to adopt conceptual-change strategies that directly challenge anthropocentric reasoning and facilitate the cultivation of a coherent scientific understanding.

Keywords: anthropocentric misconceptions; pre-service teachers; physics education; scientific literacy; mechanical forces

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1. Introduction

Research in physics education has consistently emphasized the enduring presence of intuitive yet scientifically erroneous concepts regarding fundamental forces among learners of all ages. These misconceptions endure even among university students and pre-service teachers, whose professional training should ideally provide them with accurate conceptual frameworks (Kotsis, 2023; Levy & Moore Mensah, 2021; Stylos et al., 2008; Suhandi et al., 2025). As pre-service teachers are poised to become the principal disseminators of scientific knowledge to young children, their comprehension of fundamental physical concepts presents both an opportunity and a challenge for the reform of science education (Kotsis & Gavrilas, 2025).

The forces of gravity, friction, buoyancy, and aerodynamic drag are particularly insightful subjects for this research. These forces manifest in quotidian phenomena and are perceptible to human senses; however, their fundamental mechanisms are abstract and frequently counterintuitive. Previous research has revealed prevalent misconceptions regarding these concepts, such as the belief that friction intentionally "prevents" motion (Kızılcık et al., 2021), that buoyant force is exclusively dictated by an object's weight rather than fluid displacement (Bozkurt & Yıldırım, 2022), and that air resistance functions as a deliberate force opposing motion to "slow objects down," rather than being a function of velocity and surface area (Levy & Moore Mensah, 2021). Although students can articulate formulas, their explanations often depend on teleological or anthropocentric reasoning, indicating that rote knowledge does not inherently supplant foundational intuitive frameworks (Legare et al., 2013; Lombrozo & Carey, 2006).

Anthropocentric interpretations that prioritize humans or human requirements in physical reasoning constitute a distinct category of these fallacies. For instance, students might claim that "gravity exists to prevent individuals from floating away" or that "friction exists to avert slipping." This reasoning illustrates the cognitive predisposition to ascribe purpose or design to natural phenomena, a tendency that continues into adulthood unless specifically addressed through conceptual change interventions (Kelemen, 1999; Chi, 2008; Nielson et al., 2025; Dempster, 2025). The prevalence of anthropocentric reasoning among pre-service teachers is alarming, as these future educators may inadvertently perpetuate similar misconceptions in their students if their own conceptual foundations are not critically evaluated (Vosniadou, 2019). Earlier research has shown that even at the preservice level, science teachers often approach environmental and physical phenomena through anthropocentric perspectives, underscoring the persistence of human-centered reasoning in teacher education (Çobanoğlu & Karakaya, 2009). Subsequent work has further revealed that pre-service science teachers' moral and epistemological belief systems shape their reasoning about environmental and scientific issues, influencing the degree to which they adopt anthropocentric or ecocentric viewpoints (Tuncay-Yüksel, 2016). Research in biology education has shown that even instructors frequently employ anthropocentric or teleological language in classroom explanations, inadvertently reinforcing cognitive construals among students (Betz et al., 2019).

Despite extensive research on conceptual change, few studies have systematically investigated anthropocentric reasoning regarding these four mechanical forces among pre-service teacher populations. Most studies concentrate either on younger students or on specific subjects such as gravity or friction. This study investigates the anthropocentric misconceptions held by first-year pre-service teachers in a Greek university setting. This research aims to elucidate how future educators conceptualize weight, friction, buoyancy, and air resistance, thereby guiding the creation of focused instructional strategies that challenge anthropocentric reasoning and foster the formation of scientifically coherent mental models. Similar inquiries into pre-service teachers' understanding of student conceptions of force and motion have revealed significant knowledge gaps that impede effective science instruction (Yang et al., 2024).

2. Theoretical Background

Studies in science education have consistently shown that learners develop individual mental models of physical phenomena prior to formal instruction, and these models frequently differ from established scientific explanations (Chi, 2008; Stylos et al., 2021; Vosniadou, 2019). These alternative conceptions or misconceptions stem from quotidian experiences and the cognitive necessity to formulate coherent explanations for observable phenomena. Due to their internal consistency and practical utility in everyday life, these ideas exhibit significant resistance to alteration (diSessa, 2022). Theory of conceptual change posits that effective science education must confront these ingrained notions directly, rather than simply presenting accurate in-formation, to cultivate profound comprehension (Posner et al., 1982; Potvin & Hasni, 2014).

Among various alternative conceptions, anthropocentric reasoning holds a unique status. Anthropocentrism denotes the interpretation of natural phenomena with a focus on human agency or purpose, exemplified by the belief that rain falls "to water plants" or that gravity exists "to prevent people from floating away." Piagetian theory delineates an initial stage of ego-centrism in childhood cognition, wherein children formulate explanations centered on themselves (Piaget, 1989). As children develop, egocentrism generally transitions to a more expansive anthropocentrism, wherein humans continue to serve as the primary reference point, even as the individual self diminishes (Carey, 1985). Despite the objective of formal education to supplant these explanations with mechanistic, non-teleological reasoning, research indicates that anthropocentric patterns may endure into adolescence and adulthood (Legare et al., 2013).

Physics education offers an excellent opportunity to analyze such reasoning, as numerous physical forces are imperceptible and counterintuitive. Research on gravity, friction, and buoyancy consistently reveals that learners, including university students and pre-service educators, frequently depend on purpose-driven or anthropocentric explanations when they are unable to remember or utilize formal scientific concepts (Kızılcık et al., 2021; Bozkurt & Yıldırım, 2022; Stefanou et al., 2023). For instance, students might claim that friction exists "to prevent objects from sliding," presenting the phenomenon as though nature were tailored to fulfill human requirements. These explanations are not mere linguistic shortcuts; instead, they represent a profound cognitive mechanism wherein teleological and anthropocentric reasoning function as default explanatory strategies when causal mechanisms are unclear (Kelemen, 1999; Lombrozo & Carey, 2006).

The prevalence of anthropocentric fallacies among pre-service educators is notably significant. As prospective educators, these individuals will convey their conceptual frameworks to primary school students, potentially reinforcing rather than rectifying intuitive yet scientifically erroneous notions (Levy & Moore Mensah, 2021). Models of conceptual change highlight that educators' scientific comprehension and their recognition of students' potential misconceptions are essential elements in crafting instruction that fosters precise scientific reasoning (Vosniadou, 2019; Potvin & Hasni, 2014). When pre-service teachers maintain anthropocentric explanations for fundamental forces like weight, friction, buoyancy, and air resistance, they jeopardize the eradication of misconceptions that science education aims to address.

3. Materials and Methods

This study employed a descriptive survey design to investigate the anthropocentric misconceptions of pre-service teachers regarding the forces of weight, friction, buoyancy, and air resistance. A survey approach was deemed appropriate because it allows the systematic collection of spontaneous explanations for physical phenomena and facilitates the categorization of misconceptions across a relatively large sample (Creswell & Creswell, 2018). The study focused on identifying the presence and frequency of anthropocentric reasoning rather than testing a specific instructional intervention.

The research was conducted during the spring semester of the 2023–2024 and 2024-2025 academic years at the University of Ioannina in Greece. The sample included 476 first-year pre-service teachers enrolled in the Pedagogical Department of Primary Education. At the time of data collection, participants had completed only one year of university studies and had recently transitioned from secondary education. Demographically, 85% of the participants were female (n = 404) and 15% were male (n = 72), reflecting the typical gender distribution of primary education programs in Greece. Participation was voluntary, and all responses were anonymous. Ethical approval was obtained from the departmental research committee, and informed consent was secured from all participants in accordance with the Declaration of Helsinki.

Data were gathered using a single open-ended question administered in written form during a scheduled course session. Students were asked:

"What are the forces due to (a) weight, (b) friction, (c) fluid buoyancy, and (d) air resistance?"

The question was intentionally succinct to provoke participants' immediate conceptualizations instead of eliciting memorized definitions from textbooks. All four concepts were instructed in the previous semester as part of the physics education curriculum, guaranteeing that participants received at least a foundational exposure to the scientific explanations..

Responses were transcribed verbatim and subjected to qualitative content analysis (Miles et al., 2020). Two independent coders first read all responses to identify recurrent patterns and develop an initial coding scheme. Through iterative discussion, six mutually exclusive categories were established: (1) correct scientific explanation (responses consistent with accepted physics principles); (2) nature of the medium (explanations attributing the force to inherent properties of the substance (e.g., "weight exists because matter has mass")); (3) anthropocentric reasoning (explanations centering on human needs or purposes (e.g., "friction exists so that people do not slip")); (4) misapplication of Newton's third law (statements treating each force as a "reaction" to weight); (5) mathematical equation (responses giving only a formula without a conceptual explanation); and (6) other or no answer (statements that could not be classified or blank responses).

Interrater reliability was assessed using Cohen's kappa, resulting in a coefficient of 0.87, signifying robust agreement (McHugh, 2012). Discrepancies were reconciled through consensus. After this, frequency counts and percentages were computed for each category and for each of the four forces.

Various strategies were employed to augment the credibility of the findings. The coding process initially employed independent coders and consensus discussions to mitigate subjectivity. The categorization scheme was guided by established research on misconceptions in physics (Kızılcık et al., 2021; Bozkurt & Yıldırım, 2022). The substantial sample size facilitated reliable estimates of category frequencies and enhanced the external validity of the findings

4. Results

The analysis of the 476 complete questionnaires revealed that scientifically accurate explanations were most frequently recorded for the force of weight and least for air resistance, as presented in Table 1. Across all four forces, anthropocentric reasoning emerged as a distinct and persistent type of response. Although only 10–12% of students provided anthropocentric explanations for each individual force, a larger proportion (18.1%, n = 86) offered at least one such response across the four items. This finding suggests that nearly one in five pre-service teachers continue to rely on human-centered explanatory frameworks despite having received formal instruction on these topics. Furthermore, the distribution of responses differed notably among the four forces, indicating that students' levels of understanding were not uniform.

With regard to weight, 63% of students provided scientifically accurate explanations, making it the force with the highest rate of correctness. However, anthropocentric reasoning was still evident, as 11.8% of respondents argued that weight exists to keep humans and objects on the ground. Additionally, 8.8% attributed weight to the inherent properties of the body, such as the presence of mass. When students discussed friction, the percentage of correct answers declined to 52.5%. At the same time, 9.2% of participants expressed anthropocentric views – such as suggesting that friction exists to prevent people from slipping – while 13.0% attributed friction to intrinsic characteristics of surfaces.

As the focus shifted to buoyancy, the frequency of correct explanations dropped substantially to 29.0%. Anthropocentric reasoning remained present, with 12.2% of students describing buoyancy as a force that allows humans or fish to float. Moreover, misconceptions involving incorrect applications of Newton's third law became more prevalent in this context (9.7%). Similar deficiencies in teachers' understanding of the upthrust concept have also been identified among in-service educators, underscoring the widespread and persistent nature of such misconceptions (Ramma et al., 2024). The weakest scientific understanding was observed in relation to air resistance. Only 14.7% of students provided accurate explanations, whereas 22.1% offered mathematical descriptions devoid of conceptual reasoning. Although students struggled with scientific interpretations, anthropocentric explanations persisted (10.7%), including claims like the idea that air resistance exists so humans can use parachutes to fly.

Taken together, these findings, summarized in Table 1, indicate not only a decline in scientific accuracy from weight to air resistance but also the enduring nature of anthropocentric reasoning across all forces. This persistence highlights the robustness of everyday explanatory frameworks even among individuals training to become teachers.

Table 1. Percentages of student responses by category for each force.

Category of Response	Weight (%)	Friction (%)	Buoyancy (%)	Air Resistance (%)
Correct scientific answer	63.4	52.5	29.0	14.7
Nature of the medium	8.8	13.0	16.0	21.0
Anthropocentric reasoning	11.8	9.2	12.2	10.7
Mathematical equation	3.8	8.0	15.1	22.1
Misapplication of Newton's 3rd law	0.0	0.0	9.7	11.3
Other or no answer	12.2	17.3	18.0	20.2

Note: Percentages may not sum exactly to 100 due to rounding.

Further analysis focused on the 43 students (18.1%) who provided at least one anthropocentric explanation. Gender distribution within this subgroup (87% female, 12% male) mirrored that of the total sample, suggesting that anthropocentric reasoning was not strongly associated with gender. Previous research, however, has shown that sex and grade level can significantly influence misconceptions about force and motion, emphasizing the complex interplay of cognitive and contextual factors in physics learning (Wancham et al., 2023).

Within this subgroup, anthropocentric explanations were not evenly distributed across forces. Weight elicited the greatest proportion of single-force anthropocentric responses (60% of the subgroup), followed by air resistance (58%), friction (49%), and buoyancy (58%), supporting earlier findings on students' alternative ideas about force and weight (Kotsis & Stylos, 2023). A closer inspection of cross-force patterns revealed that:

- 33% of this subgroup used anthropocentric reasoning for exactly one force,

- 30% for two forces,
- 16% for three forces,
- and 21% (equivalent to 3.8% of the entire sample) for all four forces.

This pattern suggests that while some pre-service teachers display isolated anthropocentric misconceptions, a smaller but significant fraction consistently applies human-centered reasoning across a broad range of physical phenomena.

A qualitative examination of the written statements reveals the nature of anthropocentric reasoning. Typical examples include:

- *"Weight exists so that people and animals do not float away."*
- *"Friction is there so we can walk without slipping."*
- *"Buoyancy allows humans and fish to stay on the water's surface."*
- *"Air resistance is what enables humans to fly with a parachute."*

These statements indicate an implicit teleology, portraying physical forces as if they are intended to fulfill human needs or purposes. This reasoning frequently coexisted with accurate or partially accurate explanations for other forces within the same participant, highlighting the fragmented and context-dependent characteristics of these mental models (Chi, 2008; Vosniadou, 2019).

The data indicate that anthropocentric misconceptions endure among first-year pre-service teachers, notwithstanding recent physics instruction. Although numerous students can provide accurate scientific explanations, especially regarding weight, a significant number still comprehend less familiar forces, such as buoyancy and air resistance, through anthropocentric perspectives. The existence of a small cohort that uniformly employed anthropo-centric reasoning across all four forces underscores the necessity for focused conceptual change strategies in teacher education.

5. Discussion

The results of this study indicate that anthropocentric reasoning continues to be a prominent aspect of the conceptual framework of pre-service teachers, despite their formal education in basic physical forces. Almost twenty percent of participants utilized hu-man-centered explanations for at least one of the four examined forces, while a smaller but significant subgroup consistently employed anthropocentric reasoning across all four. These findings corroborate earlier studies indicating that intuitive, purpose-driven explanations exhibit considerable resilience, frequently enduring into adulthood despite extensive formal science education (Chi, 2008; Kelemen, 1999; Vosniadou, 2019).

The endurance of anthropocentric fallacies can be elucidated through conceptual change theory, which highlights the challenge of supplanting entrenched intuitive models with scientific paradigms (Posner et al., 1982; Potvin & Hasni, 2014). Students' anthropocentric explanations, such as asserting that "friction exists to prevent human slipping" or "air resistance enables humans to parachute," exemplify what Kelemen (1999) termed promiscuous teleology: a cognitive inclination to ascribe purpose or design to natural occurrences. This inclination is beneficial in early childhood as it offers swift, seemingly coherent interpretations of intricate events; however, it hinders science education when it conflicts with mechanistic reasoning (Legare et al., 2013; Lombrozo & Carey, 2006).

The observation that students were more inclined to provide accurate explanations for weight compared to buoyancy or air resistance is consistent with prior research indicating that concepts closely associated with everyday physical experiences are more easily integrated into scientific understanding (Levy & Moore Mensah, 2021). Weight is perceived continuously and reinforced by gravitational sensations, while buoyancy and air resistance are encountered less frequently in contexts necessitating explicit reasoning. The low accuracy rates for air resistance and the high incidence of purely mathematical responses indicate that students may memorize formulas without incorporating them into cohesive causal frameworks (Suhandi et al., 2025). Such "equation-centered" responses signify superficial comprehension and underscore the constraints of conventional pedagogy, which frequently prioritizes problem-solving.

The prevalence of anthropocentric reasoning among pre-service teachers is particularly alarming, as these individuals will soon be tasked with imparting essential physical principles to young learners. Educators' misconceptions can affect lesson design, interpretation of student inquiries, and assessment of explanations, thus perpetuating erroneous concepts across generations (Bozkurt & Yıldırım, 2022; Kızılcık et al., 2021; Panagou et al., 2024).

Teacher education programs must incorporate explicit instruction on prevalent student misconceptions, opportunities for metacognitive reflection, and pedagogical strategies to address intuitive yet erro-neous reasoning (Potvin & Hasni, 2014). Integrating a literacy focus in science instruction – particularly by strengthening preservice teachers' awareness of semantic gravity and their ability to shift between everyday and scientific language – h as been shown to enhance conceptual understanding and disciplinary communication (Sigsgaard & Preston, 2025). Moreover, evidence indicates that teachers' co-constructive discourse practices -where reasoning is collaboratively developed through classroom dialogue—can significantly enhance students' self-related cognitions and interest in primary science learning (Schulze et al., 2025). Interventions including conceptual conflict tasks, guided inquiry, and e-rebuttal texts have demonstrated efficacy in promoting the development of scientifically accurate mental models among students (Schroeder & Kucera, 2022; Suhandi et al., 2025). Recent evidence further indicates that integrating refutation with visualization and consolidation in a triadic instructional design can substantially enhance text comprehension and conceptual change (Kröger et al., 2025). Beyond content generation, artificial intelligence applications – particularly those utilizing natural language processing – are increasingly employed to detect and analyze students' misconceptions in science learning contexts. Complementary advancements in automated assessment design, such as systems for automatic item generation targeting misconceptions about force and motion, further enhance the diagnostic capabilities available to educators (Wancham et al., 2023). More broadly, comprehensive reviews have demonstrated that artificial intelligence is transforming educational practice through adaptive feedback, personalized learning, and data-driven pedagogy across disciplines (Wang et al., 2024).

Moreover, the disjointed reasoning exhibited by participants, in which students provided accurate explanations for certain forces while offering anthropocentric interpretations for others, highlights the necessity for instruction that promotes integrated conceptual understanding rather than mere isolated facts. Strategies including model-based reasoning, argument-driven inquiry, and explicit discourse on the nature of science can assist prospective educators in constructing coherent frameworks that remain robust across various contexts (Windschitl et al., 2008).

This study is constrained by its cross-sectional design and dependence on self-reported written responses. Conversely, the open-ended question elicited spontaneous reasoning; subsequent interviews or think-aloud protocols could yield deeper insights into the cognitive mechanisms underpinning anthropocentric explanations. Future research may investigate the effects of targeted instructional interventions on the prevalence of anthropocentric reasoning, compare outcomes across cultural contexts, or longitudinally monitor conceptual change throughout teacher education programs.

The findings indicate that anthropocentric reasoning is not simply a remnant of childhood cognition but a persistent cognitive default that necessitates intentional instructional focus. Rectifying these misconceptions in teacher education is crucial to avert their perpetuation in future generations and to develop scientifically literate educators capable of fostering profound conceptual comprehension in their classrooms.

6. Conclusions

This study illustrates that anthropocentric reasoning regarding fundamental physical forces poses a considerable challenge for pre-service teachers. Approximately 20% of participants provided at least one human-centered rationale for the phenomena of weight, friction, buoyancy, or air resistance, with a smaller yet significant subgroup consistently employing this reasoning across all four concepts. These findings suggest that intuitive explanations based on human purpose persist alongside, and occasionally supersede, the scientific concepts presented in university-level physics courses.

Of the four forces analyzed, weight produced the greatest percentage of accurate scientific explanations, indicating its direct relevance to daily life. Conversely, buoyancy and air resistance were the least comprehended, as numerous students either offered incomplete mathematical representations or ascribed intentional functions to these phenomena. The disparate allocation of accurate and anthropocentric responses among the forces underscores the fragmented quality of participants' conceptual frameworks. Students often exhibited sound reasoning regarding one force but frequently defaulted to anthropocentric or teleological explanations for others, indicating that their understanding is context-dependent and fragmented.

These findings have significant implications for teacher education. Pre-service teachers who hold anthropocentric misconceptions may unintentionally convey them to their future students, thereby perpetuating cycles of misunderstanding in elementary science education. Teacher education programs should thus integrate specific strategies to address and rectify these misconceptions. These strategies may encompass direct discourse on prevalent alternative conceptions, opportunities for metacognitive reflection, and pedagogical methods that prioritize mechanistic explanations and model-based reasoning over mere rote memorization of formulas.

The findings indicate a necessity for continuous research and curriculum advancement. Future research may investigate the efficacy of interventions aimed at diminishing anthropocentric reasoning, analyze cross-cultural patterns of misconceptions, or monitor conceptual evolution during teacher preparation programs. Confronting these challenges is crucial for improving the scientific literacy of pre-service teachers and guaranteeing that future students receive education grounded in precise and coherent physical principles.

Data Availability Statement: The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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Institutional Review Board Statement: The study was conducted in accordance with the ethical standards of educational research. All procedures involving student participants were reviewed and approved by the appropriate institutional and school authorities in Greece. Participation was voluntary, parental consent and student assent were obtained prior to involvement, and data were collected and analyzed anonymously to ensure confidentiality.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Conflicts of Interest: The author declares no conflict of interest.

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