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# Exploratory Factor Analysis (EFA) of PhET Simulation-Based Innovation in Rigid Body Equilibrium Learning to Enhance Students' Conceptual Understanding

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## ABSTRACT

**Objective:** This study aimed to analyze the validity and reliability of an instrument developed to measure students' perceptions of PhET simulation-based innovations in learning rigid body equilibrium. The research sought to determine whether the instrument accurately captured students' conceptual understanding, engagement, and satisfaction while also identifying latent factors underlying their responses through Exploratory Factor Analysis (EFA). **Method:** The study employed a quantitative survey approach with 25 Likert-scale items distributed to students in one secondary school. Data were analyzed using descriptive statistics, Kaiser-Meyer-Olkin (KMO), and Bartlett's test for sampling adequacy, followed by EFA with Varimax rotation. Reliability testing was conducted through Cronbach's Alpha to evaluate the internal consistency of extracted factors. **Results:** The findings revealed that the instrument achieved strong overall reliability (Cronbach's  $\alpha = .909$ ). EFA identified nine distinct factors, extending beyond the original five theoretical dimensions of ease of use, engagement, conceptual clarity, collaboration, and satisfaction. While the first five factors demonstrated high reliability ( $\alpha > .75$ ), Factors 6–9 exhibited weaker reliability, indicating the need for refinement. These results confirm that PhET simulations effectively enhance conceptual understanding and engagement, but also reveal additional dimensions of students' learning experiences. **Novelty:** This study contributes to physics education research by providing a validated multidimensional instrument for evaluating PhET-based learning in rigid body equilibrium. The emergence of nine empirical factors highlights the complex nature of students' perceptions and underscores the need for more nuanced measurement tools. Unlike prior research focusing solely on conceptual gains, this study emphasizes the psychometric validation of students' experiences, offering a novel framework for assessing technology integration in physics education.

## INTRODUCTION

In physics education, there is a strong expectation that students will not only master formulas but also develop a deep conceptual understanding of fundamental mechanics topics such as rigid body equilibrium (Galili & Goren, 2023; Batlolona et al., 2024; Gasparini et al., 2025). Conceptual understanding is essential because it enables learners to transfer knowledge across contexts and to apply physics principles in real-world problem solving (Maftuh, 2023; Simeon et al., 2022). One of the promising innovations in this regard is the use of interactive simulations such as Physics Education Technology (PhET) (Banda & Nzabanimana, 2021, 2023). PhET simulations provide dynamic visualizations, manipulable parameters, and immediate feedback, allowing students to construct mental models of physical phenomena (Saudelli et al., 2021). Empirical studies