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The Hermeneutics of Virtual Physics Education: A Postphenomenological Inquiry into Students' Experiences with Simulations and Virtual Labs

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Abstract

Virtual Virtual education has expanded rapidly since COVID-19, yet concerns remain about deep conceptual learning in physics, where embodied engagement with physical phenomena is essential. Drawing on postphenomenology and Ihde's hermeneutic relations, this qualitative study explored high school students' experiences of virtual physics education through digital technology mediation. Twenty-five Grade 10 and 11 students with at least one year of virtual physics experience participated in semi-structured online interviews. Thematic analysis, supported by member checking, expert review, and collaborative validation, revealed two dimensions of digital technologies' affordances: technology use, including expanded laboratory opportunities, accessibility, repeatability, reduced experimental errors, and learner agency; and digital content representation, including attractiveness, focused attention, visualization of abstract concepts, and detailed scientific processes. However, participants identified three irreplaceable characteristics of real laboratories: simultaneity with authentic classroom events, direct physical engagement with natural phenomena, and greater realism and credibility of observations. Thus, while digital technologies enrich physics instruction, meaningful conceptual understanding remains dependent on embodied, situated experiences. Effective physics education should integrate digital technologies with face-to-face experimentation to preserve embodied cognition while benefiting from digital affordances.

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Extended Abstract

Introduction

Digital technologies have become an established part of physics education, opening new possibilities for experimentation through virtual laboratories, simulations, and interactive visualisations. Their educational value, however, cannot be understood simply in terms of efficiency or improved access to laboratory activities. More fundamentally, these technologies alter the way learners encounter and interpret physical phenomena. The question is therefore not only whether digital tools support learning, but how they reshape students' experience of making sense of the natural world. Although previous research has demonstrated the instructional benefits of virtual laboratories, most studies have evaluated learning outcomes rather than examining the experiences through which understanding develops. This distinction is particularly important in physics, where conceptual understanding is closely connected with observation, experimentation, and bodily engagement with physical phenomena. A postphenomenological perspective shifts attention from technology itself to the relationships it mediates between learners and the world. Drawing on Don Ihde's concept of hermeneutic human–technology–world relations, this study explores how digital laboratory tools influence high school students' experiences of learning physics. Students' accounts are then interpreted through the complementary perspective of grounded, embodied, and situated cognition to better understand how technological mediation shapes conceptual learning.

Method

The study adopted a qualitative postphenomenological approach. Twenty-five Iranian high school students who had experienced at least one academic year of virtual physics instruction participated in semi-structured online interviews. Rather than seeking to evaluate digital technologies, the interviews focused on how students experienced learning physics through simulations, virtual laboratories, animations, and other digital resources. The interview data were analysed using open, axial, and selective coding. This process identified recurring experiential meanings before organising them into broader themes that captured common patterns across participants' accounts. The resulting themes were subsequently interpreted through the framework of grounded, embodied, and situated cognition. The trustworthiness of the analysis was strengthened through participant validation, expert review of the interview protocol, careful documentation of the analytical process, and independent examination of the coding by experienced physics teachers and educational researchers.

Results

Students' experiences converged around two closely connected themes. The first theme concerns the possibilities created by digital environments for learning physics. Participants described virtual laboratories as extending the range of experiments available to them while making experimentation more accessible, repeatable, and less constrained by cost, safety, or laboratory equipment. Simulations also allowed students to manipulate variables independently and observe immediate changes in physical systems. Beyond these practical advantages, digital representations helped visualize abstract concepts, reveal otherwise hidden processes, enlarge fine details, and focus attention on essential features of physical phenomena. Students frequently described these characteristics as making difficult concepts easier to interpret. The second theme concerns the distinctive role of embodied participation in experimentation. Despite recognizing the strengths of digital technologies, students consistently distinguished virtual experience from direct engagement with the physical world. Handling laboratory equipment, observing real events

as they unfolded, interacting with classmates, and experiencing experiments through multiple senses were regarded as integral to meaningful understanding. Participants repeatedly emphasized that physically performing an experiment or even observing another person perform it provided a stronger sense of authenticity and confidence than interacting with computer-generated simulations alone.

Discussion

The findings suggest that digital technologies do more than provide alternative ways of presenting scientific content. They mediate how physical phenomena become available for perception and interpretation. From a postphenomenological perspective, simulations do not simply reproduce reality; they reorganise it by highlighting certain features while simultaneously placing others in the background. Their educational value therefore lies in a distinctive form of technological mediation rather than in technological sophistication alone. Viewed through the lens of grounded, embodied, and situated cognition, students' experiences indicate that conceptual understanding in physics remains rooted in embodied encounters with the natural world and in learners' prior lived experiences. Digital technologies enrich perception by making invisible processes visible and by supporting the interpretation of complex phenomena, yet they cannot fully recreate the experiential conditions through which scientific concepts acquire meaning. Rather than viewing virtual laboratories as substitutes for physical experimentation, the findings support an integrative approach in which digital technologies complement embodied experience. Designing physics learning environments from this perspective means attending not only to the affordances of digital tools, but also to the lived, bodily, and situated experiences through which learners come to understand the physical world.

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