

“Simulations Over Specimens: Rethinking Hands-On Science Learning in a Virtual World”

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Recent developments in science education show a growing shift from traditional physical experiments toward virtual simulations as learning tools. Papalazarou et al. (2024) explain that virtual laboratory environments are increasingly being used to replace or supplement physical experiments, especially when access to real laboratory materials is limited. Their study highlights that virtual simulations allow students to manipulate variables and repeat experiments freely, which improves conceptual understanding. This shift reflects a broader trend in education where digital tools are becoming central to how scientific knowledge is taught and experienced.

Similarly, Krüger et al. (2022) emphasize the effectiveness of computer simulations compared to hands-on physical experiments in science learning. Their findings show that both methods can lead to similar learning outcomes, but simulations often provide clearer visualization of complex or abstract scientific processes. They also note that virtual environments reduce the difficulty of managing physical materials, allowing students to focus more on scientific reasoning. This suggests that the shift toward simulations may enhance learning efficiency in certain contexts.

The study by Tsirolnikov et al. (2023) further supports the growing importance of virtual laboratories in modern education. Their research found that immersive virtual lab simulations improve student engagement and maintain strong academic performance in science subjects. They also highlight that virtual learning environments became essential during the COVID-19 pandemic when physical lab access was restricted. This demonstrates that virtual simulations are not only an alternative but also a practical solution in situations where traditional experiments are not possible.

Virtual laboratories in biology help students visualize complex cellular processes that are difficult to observe in physical specimens, improving understanding of abstract concepts, as highlighted by Navarro et al. (2024). Similarly, although students often prefer hands-on physical labs, virtual laboratories are still effective and serve as a useful alternative when real materials are unavailable, as noted by Bugarso et al. (2021).

Overall, the reviewed studies show that the shift from physical experiments to virtual simulations has a significant impact on student learning. While physical experiments remain valuable for developing hands-on skills and real-world laboratory experience, virtual simulations enhance conceptual understanding, accessibility, and flexibility in science education. The evidence suggests that simulations are not simply replacements but powerful complementary tools that reshape how science is taught. Therefore, the future of science education is likely to involve a balanced integration of both physical and virtual learning environments to maximize student learning outcomes.

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