Chapter 2
A Technology-Enhanced Learning Perspective on Educational Robotics in Vocational Teacher Education

Fadip Audu Nannim
http://orcid.org/0000-0002-6452-5602
University of the Free State, South Africa

Moeketsi Mosia
http://orcid.org/0000-0002-7189-0018
University of the Free State, South Africa

Felix O. Egara
http://orcid.org/0000-0002-6249-9615
University of the Free State, South Africa

ABSTRACT

This chapter explores the transformative role of educational robotics as a Technology-Enhanced Learning (TEL) tool in vocational teacher education within Industry 4.0. Robotics equips educators with digital literacy, creativity, and adaptability, preparing learners for technology-driven workplaces. Drawing on constructivist and constructionist theories, the Technological Pedagogical Content Knowledge (TPACK) framework, and 21st-century skills, the chapter shows how robotics fosters problem-solving, collaboration, and competency-based training. Case studies from Africa, alongside perspectives from Asia, Europe, and North America, highlight

DOI: 10.4018/979-8-3373-5865-9.ch002

successes and challenges. Barriers at institutional, teacher, and student levels are analysed, with solutions emphasising policy alignment, collaboration, and professional development. Future directions include AI-driven robotics, virtual labs, and global partnerships. The chapter concludes that educational robotics is a strategic necessity for creating equitable, sustainable, and future-ready vocational teacher education worldwide.

1. INTRODUCTION

We find ourselves in a historic moment as the world speeds towards the Fourth Industrial Revolution (Industry 4.0). Imagine a flexible and agile vocational teacher helping students learn how to program a collaborative robot to weld, assemble, or troubleshoot skills that were previously only found on factory floors but are now being used in teacher education settings. These scenes are no longer fictional but a reality in classrooms; it's quickly taking over as the new standard. The reason we are having this discussion now is that the convergence of digital transformation, robotics, and global vocational training is not only coming soon, but is now happening, and teacher educators must be ready to drive change rather than react to it.

The transition to Industry 4.0 raises the urgency for teacher education programs to adjust simultaneously as smart automation, artificial intelligence, and robotics are introduced to vocational sectors globally. Although assessing themselves as highly capable, many TVET teachers in South Africa (Holler et al., 2023), Nigeria (Olusojioloba, 2023) and other African countries (Agolla, 2022) report being unfamiliar with 4IR technologies, highlighting a concerning digital competence reality gap. Although modernising vocational training is becoming a more important policy priority, little is known about how teacher educators are really prepared, particularly in settings with limited resources.

According to existing research, educational robotics can improve student attitudes, engagement, and outcomes (Nannim et al., 2025a). In STEM fields, for example, the effect sizes are moderate to significant ($g \approx 0.49$ for learning outcomes, $g \approx 0.66$ for performance; however, this is less the case for computational thinking) (Ouyang & Xu, 2024). However, the research also highlights certain drawbacks: Few studies examine whether robotics fosters the development of higher-order skills like computational thinking, and many are short-term and lack longitudinal data (Ouyang & Xu, 2024; Nannim et al., 2024a). Beyond the technical advantages, a systematic review also pointed out that implementing robotics presents learner challenges like the novelty effect, where initial engagement may wane over time, and teacher-related challenges like a lack of technical knowledge, standardised teaching methods, and increased workload (Wang et al., 2024).