

Effects of Intelligent Tutoring Systems on Educational Outcomes: Evidence From a Comprehensive Analysis

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ABSTRACT

This article presents a meta-analysis of the existing literature using Stata 18.0, focusing on the effects of ITSs on learning attitudes, knowledge acquisition, learner motivation, performance, problem-solving skills, test scores, and educational outcomes across different countries and educational levels ($k = 30$, $g = 0.86$). The findings suggest that while ITSs can significantly improve learning attitudes and test scores, their effects on knowledge acquisition, learner motivation, performance, and problem-solving skills are less conclusive. The impact of ITSs on educational outcomes also varies across different countries and educational levels, with no significant relationship observed between educational levels and ITS effectiveness. The use of specific ITS designs, such as game-integrated ITSs and ITSs with worked examples, appears to have a more positive impact on educational outcomes. Future research should consider the differential effects of ITS designs and explore ways to enhance their impact on diverse learners and educational contexts.

KEYWORDS

Intelligent Tutoring System, Type, Educational Outcome, Educational Level, Country

INTRODUCTION

Intelligent Tutoring Systems (ITSs) are educational tools based on computer technologies, which are able to provide personalized learning for students (Ahmad et al., 2021). They analyze students' performance and adjust teaching strategies according to students' needs and progress using artificial intelligence (AI) technologies. They can not only provide educational contents, but also identify the fields where students need extra assistance. They can integrate different teaching methods, e.g. exemplar demonstration, visualized tools, and interactive exercises, to catalyze students' interest and enhance their understands of concepts (Alzoubi et al., 2020). ITSs can improve students' academic achievements and satisfaction, especially when they are combined with human teachers.

It is important to investigate the effect of ITSs on educational outcomes (Wang et al., 2021). These systems can provide personalized learning and enhance learners' engagement, leading to improved

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academic achievements and satisfactory educational experiences (Chu et al., 2022). Educators could obtain suggestions about effective teaching and find out the methods to improve learning outcomes through analyzing the influence of ITSs. The effectiveness of ITSs is conducive to the demonstration that ITSs can be used in education and more investment in educational technologies is necessary (Abersek & Popov, 2004). With the sustainable development of educational technologies such as ITSs, students with different background can enjoy the personalized learning opportunities.

There is a significant research gap between ITSs and their effects on educational outcomes. However, there is a paucity of meta-analyses regarding this topic, which has widened the gap (Hillmayr et al., 2020). A significant research gap is the lack of the standardized evaluation and indicators of the effects of ITSs on educational outcomes (Santos & Jorge, 2013). Different researchers adopt different research methods and evaluation criteria, which makes it hard to compare and synthesize the results. Most of the present studies focus on short-term research achievements, ignoring the long-term effects of ITSs on learning achievements and student development (du Boulay, 2021). To fill in this research gap, it is necessary to carry out a meta-analysis to combine various research results for a comprehensive understanding. This study aims to comprehensively and meta-analytically focus on the effects of ITSs on educational outcomes, moderated by educational levels, ITSs types, areas, and countries.

LITERATURE REVIEW

Theoretical Framework

A key indicator evaluating the effects of ITSs on educational outcomes is educational achievement including attitude, knowledge, motivation, performance, problem-solving ability, and test scores. Each achievement can reflect different aspects of students but all of the achievements are mutually connected and under the influence of various factors. The hypotheses regarding ITS, teaching methods, course design, and educational technologies aim to improve these educational achievements. For instance, a hypothesis may predict that practical operation will improve students' learning motivation and problem-solving skills. Meanwhile, another hypothesis may showcase that the ITS based on AI technologies can improve students' attitudes and test scores (Yu & Wang, 2014). These research hypotheses can promote students' comprehensive development by exploring and optimizing educational practice.

The Effect of ITSs on Learning Attitudes

It is noteworthy to find that the effects of ITSs on learning attitudes are inconsistent. While some studies have reported positive effects of ITSs on learning attitudes (Gaeta et al., 2014), others reported negative effect of ITSs on learning attitudes (Cabada et al., 2020). One possible explanation for the inconsistent findings is the lack of individualized feature in the use of ITSs. It is possible that students feel ITSs fail to cater to their individual needs or preferences, leading to the decrease of satisfaction and motivation. Besides, the type and interface of ITSs can significantly influence users' experiences and finally exert a great influence on learning attitudes. Researchers should shed light on the positive and negative influencing factors in the use of ITSs (Bellhäuser et al., 2016). The factors include personalized learning, feedback quality, teaching styles, and course goals. Educators and developers could design effective ITSs and shape positive learning attitudes by investigating these influencing factors.

The Effect of ITSs on Knowledge Acquisition

It is important to further investigate the effect of ITSs on knowledge acquisition, which is a multifaceted issue. While ITSs may potentially improve learning achievements and maintain knowledge, the fact may remain questionable (Adesanya, 2012). The reason may be that ITSs is limited

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