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Side Effects of Technological Practices on 21st-century Skills of Gifted Students

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Abstract

Part of the research has focused on developing new technologies that contribute to fostering 21st-century skills in gifted students. However, some authors warn that the improper use of these technologies may lead to generations of passive users rather than critical thinkers, creators, and problem solvers for society. The objective of this study is to analyze the side effects of technological practices on the development of 21st-century skills in gifted students. To this end, a systematic review of articles published between 2010 and 2025 was conducted, following the PRISMA declaration guidelines. The final selection consisted of 40 articles, whose risk of bias was assessed using the Cochrane RoB 2 tool for randomized controlled trials and the ROBINS-I tool for non-randomized studies. Findings indicate that, although the use of new technologies has enormous potential for developing 21st-century skills in gifted students, the current education system may be fostering a lack of motivation for deep learning and creative production, ultimately leading to the misuse of these tools.

Keywords

Technology, artificial intelligence, giftedness, motivation, creativity

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Efectos Secundarios de las Prácticas Tecnológicas en las Habilidades del Siglo XXI de los Estudiantes con Alta Capacidad

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Resumen

Parte de la investigación se ha centrado en el desarrollo de nuevas tecnologías que contribuyan a fomentar las habilidades del siglo XXI en estudiantes con alta capacidad (AC). Sin embargo, algunos autores advierten que el uso inadecuado de estas tecnologías puede dar lugar a generaciones de usuarios pasivos en vez de pensadores críticos, creadores y aptos para solucionar problemas de la sociedad. El objetivo de este estudio es analizar los efectos secundarios de las prácticas tecnológicas en el desarrollo de las habilidades del siglo XXI de los estudiantes con AC. Para ello se realizó una revisión sistemática de artículos publicados entre 2010 y 2025 siguiendo las directrices de la declaración PRISMA. La selección final estuvo compuesta por 40 artículos, cuyo riesgo de sesgo se evaluó utilizando la herramienta Cochrane RoB 2 para ensayos controlados aleatorios y la herramienta ROBINS-I para estudios no aleatorizados. Se ha encontrado que, aunque el uso de las nuevas tecnologías tiene un enorme potencial en el desarrollo de las habilidades del siglo XXI de los estudiantes con AC, el sistema educativo actual puede estar promoviendo la desmotivación por el aprendizaje profundo y la producción creativa y, como consecuencia, el mal uso de estas herramientas.

Palabras clave

Tecnología, inteligencia artificial, altas capacidades, motivación, creatividad

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The field of technology is rapidly developing worldwide. This technological advancement largely determines the wide variety of knowledge and skills that educational systems must integrate into their curricula to prepare students for the labor market. One of the objectives of the OECD (Organisation for Economic Co-operation and Development [OECD], 2024) is to analyze and synthesize the knowledge, skills, attitudes, and values that students need in the 21st century to thrive and create a better future both individually and socially. To this end, it has recommended the development of six skills to ensure high-quality education: global citizenship skills, innovation and creativity skills, technological skills, interpersonal skills, collaborative and problem-based learning skills, and lifelong and student-driven learning skills. However, employers have reported difficulty finding candidates who have developed these skills (Shmatko & Volkova, 2020).

There is a consensus that some profiles of gifted students could contribute significantly to a dynamic society that requires self-motivated professionals to engage in lifelong learning and innovative productions (Renzulli, 2020; Siegle, 2023; Steenbergen-Hu et al., 2020). These students excel in aptitudes related to computational thinking, such as visuospatial ability, reasoning ability, and problem-solving ability (Maker, 2020). Additionally, they are often attracted to programming because it provides an opportunity to engage in mental processes of abstraction, decomposition, algorithmic thinking, evaluation, and generalization in which they are potentially efficient and through which they can effectively solve real-world problems (Siegle, 2023). However, a discrepancy is often observed between the expected achievement based on their intellectual potential and their academic and professional performance (Steenbergen-Hu et al., 2020).

Some studies (Renzulli, 2020) have revealed that most curricula (at all educational levels) are not adequate to develop 21st-century skills in gifted students, which can lead to a significant underutilization of their academic and professional potential. Consequently, part of the research has focused on developing new technologies and methodologies that contribute to improving these skills (Babaoglu & Güven Yildirim, 2023; Alshehri & Hamoud, 2024). These methodologies range from simple block programming tasks to the use and creation of advanced technologies, such as artificial intelligence (AI).

Some authors argue that these technologies could support personalized education, optimize comprehensive learning, and foster the development of exceptional skills applicable to real-world situations, which could be an advantage over traditional educational methods and responses (Siegle, 2023; Renzulli, 2020). Others, however, warn about the undesirable effects of new technologies in curriculum implementation. For example, Siegle (2017) points out that they could promote plagiarism or cyberbullying among gifted students. Morduchowicz (2023) argues that generative AI could harm the development of critical thinking and basic communication skills, such as reading comprehension and the ability to express ideas. Meanwhile, Sternberg (2024) questions the effectiveness of generative AI for developing creativity or critical thinking: " The greatest worry in these times of generative AI is not that it may compromise human creativity or intelligence, but that it already has" (p. 69).

In reality, these effects do not have to be inseparable but rather can reflect the desirable and undesirable effects of any intervention (Zhao, 2017). Educational interventions are not universally transferable from the place where they originated. In educational practice, the populations and contexts in which technological interventions are implemented can mediate their effect and cause unexpected and even adverse side effects (Gómez-León, 2024). Considering the factors that can cause undesirable effects in the implementation of new technologies helps advance the field of education through informed decision-making about teaching methods or policies that prevent or minimize these effects.

It has been found that the way technology is used has a greater effect on students' grades than the mere use of technology itself (Brink, 2023; Hew and Cheung, 2013). In a recent meta-analysis, Ran et al. (2022) found that the learning environment and assessment method mediated the effect of technology on student performance. Specifically, collaborative and communicative environments and adaptive tests to assess students' levels and performance increased the effectiveness of technology.

Education for gifted students has its own standards for technological literacy. For example, the National Association for Gifted Children (NAGC) establishes that the implementation of technology should focus on individualizing and differentiating curricular materials and developing learning environments that foster student motivation (VanTassel-Baska, 2022). However, there is little research on the individualization, challenge, and preparation of materials in the technological practices of gifted students (Siegle, 2023; Renzulli, 2020). In their review, Alshehri & Hamoud (2024) described some of the challenges teachers faced when applying differentiation through technology, finding that an inadequate learning environment could incite gifted students to exhibit inappropriate attitudes and behaviors. Therefore, it has been suggested that, in addition to quantitative data, qualitative research would be useful to help understand how gifted students interact with technology in regular classrooms and how they and their teachers perceive their experiences. There are a limited number of literature reviews focused on showing the effectiveness of technology use in the education of gifted students (Ali & Alrayes, 2019; Alshehri & Hamoud, 2024; Brink, 2023; Gómez-León, 2025; Kontostavlou & Drigas, 2019; Tosunoğlu, 2021). The results show the potential of these practices for developing 21st-century skills in students. However, no review has been found on the possible side or undesirable effects outside the experimental context.

The objective of this research is to analyze the side effects of technological practices on the development of 21st-century skills in gifted students. This aims to answer the following research questions: What factors can limit the development of the 21st-century skills suggested by the OECD after the implementation of new technologies in the curricula of gifted students? What consequences can these limitations have on the ethical and responsible use of new technologies by gifted students?

Methodology

An exhaustive search was conducted in recognized databases in the field of educational technology, including Scopus, Web of Science, IEEE Xplore, Taylor & Francis, and ACM Digital Library, following the criteria established in the PRISMA statement (Page et al., 2022). The terms used were (“gifted” OR “talent” OR “high ability” OR “high intellectual ability”) AND (“technology” OR “robot" OR “intelligent tutoring systems” OR “coding” OR “STEM” OR “STEAM”) AND (ethics OR innovation OR creativity OR critical thinking OR problem solving OR self-regulation OR emotional OR interpersonal OR collaborative OR engagement

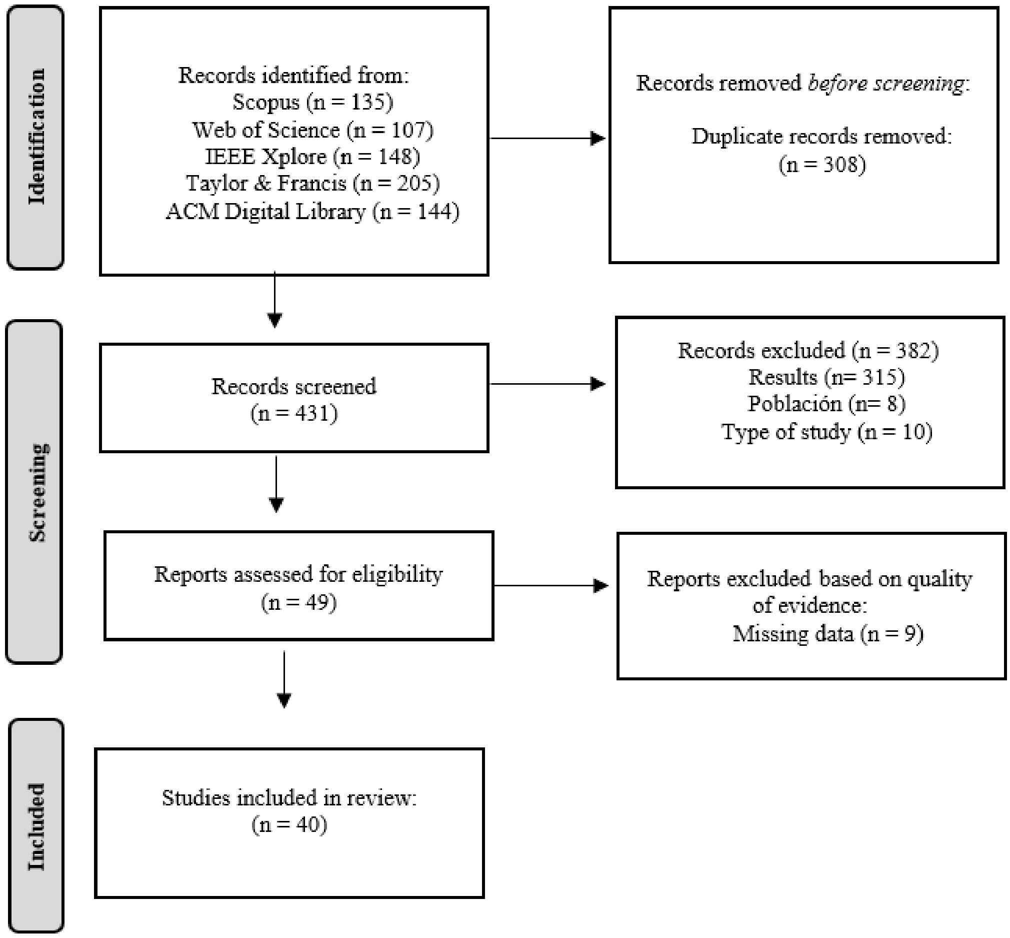
OR motivation OR computational thinking). The terms, syntax, and Boolean operators were adapted according to the database.

Interventions that incorporated new technologies and showed side effects or undesirable effects on the development of 21st-century skills suggested by the OECD (2024) in gifted students were included. In the field of systems and software engineering, the success of an intervention is measured through efficacy (magnitude of change in the dependent variable or skill), feasibility (commitment, implementation, adherence, expectations, and transfer to real life), and acceptability (affinity, usability, utility, difficulty, attractiveness, and relevance). Therefore, a wide variety of data sources were used: academic and aptitude results related to the use of technology in gifted students, and experiences and perceptions of teachers and students on the implementation of methodologies that incorporate new technologies in the context of giftedness. The search was established from the year 2010 because the implementation of new technologies in education occurred significantly and widely from this decade (Zhai et al., 2021). Peer-reviewed scientific research published in journals or conference proceedings was considered. Only primary studies were included, and all designs, qualitative, quantitative, or mixed, were considered. Studies that did not meet the inclusion criteria were excluded.

To apply the inclusion and exclusion criteria, the web-based reference management software Covidence was used. A total of 739 articles were identified, and after removing duplicate references, 431 remained. A first selection was made through the title and abstract, except when eligibility criteria could not be extracted, in which case the full article was read. The remaining 49 articles underwent a second full-text review. Two reviewers independently evaluated the quality of the selected studies. The final selection consisted of 40 articles[1] (Figure 1).

Figure 1

Flow Diagram of the Systematic Review Process



Source. Own research.

The evaluation to determine the quality of the interventions was carried out by two researchers using the EPOC data collection form (Cochrane Collaboration, 2017). Each researcher separately extracted data on important methodological characteristics such as: participant characteristics (number, age, gender), geographical distribution, sample selection method, diagnostic criteria, study design, type of technology, educational field, educational level, intervention procedure and duration, efficacy (effects on at least one of the skills suggested by the OECD); generalization; maintenance; feasibility (commitment, implementation, adherence, expectations, and transfer to real life); and acceptability (affinity, fluency, usability, utility, difficulty, attractiveness, and relevance). The Inter-Rater Agreement (IRA) reliability was 100%.

To assess the internal validity of randomized controlled trials (RCTs), the Cochrane RoB 2 tool for risk of bias in randomized trials (Sterne et al., 2019) was used, and for non-randomized studies, the ROBINS-I tool (Sterne et al., 2016) was used.

The data were classified according to the eight skills recommended by the OECD (2024) to prepare students for the new digital era: innovation and creativity skills, technological skills, interpersonal skills, collaborative and problem-based learning skills, lifelong and student-driven learning skills, and global citizenship and ethical and responsible use of new technologies.

Results

The first relevant data from the selection process is that most research tends to focus solely on demonstrating the efficacy of interventions, generally ignoring or minimizing the possible side or undesirable effects on other student skills and attitudes.

In total, the sample consisted of 2809 gifted students, 780 teachers, and 180 parents[2]. In four studies, the teachers were secondary school science and technology teachers (Abdurrahman et al., 2019; Anisimova et al., 2017; Kunt & Tortop, 2017; Miedijensky, 2018) and in three studies, they were primary and secondary school teachers (Sandri et al., 2023; Opoku et al., 2025; Yıldırım et al., 2024). 7% of the studies were conducted with students aged 7 to 12 years, 20% with students aged 6 to 14 years, and the remaining 73% with students aged 12 to 21 years. Therefore, the representation of early childhood education students is nonexistent, and primary education students are scarcely represented.

The high risk of sample selection bias in the reviewed studies may compromise the validity of the findings. First, only five studies used random sampling (Choi & Lee, 2015; Coxon, 2012; García-Perales & Almeida, 2019; Kazemi & Sayyadi, 2014; Tofel-Grehl et al., 2018), while the rest used intentional or convenience sampling. Second, 67% of the gifted students were male and 33% female. Additionally, only two studies explicitly included students from traditionally underrepresented groups in giftedness regarding race or socioeconomic status (Coxon, 2012; Maker et al., 2020). Third, 83% of the studies did not provide detailed identification criteria other than mentioning that gifted students were identified by national tests, school counseling services, academic performance, or teacher recommendations. Only five studies described multiple criteria for identifying gifted students (Jamali, 2019; Maker, 2020; Salazar Tornel et al., 2022; Sastre-Riba & Pascual-Sufrate, 2013; Zbainos & Beloyianni, 2018), and among them, only three used classifications of the giftedness profile (Maker, 2020; Sastre-Riba & Pascual-Sufrate, 2013; Zbainos & Beloyianni, 2018).

Furthermore, the validity of the findings could be threatened due to the high risk of detection and social desirability biases, where there were no single or double-blind evaluations, and participants responded to questionnaires or interviews being aware of their intervention or comparison conditions[2].

The trend analysis reveals an increase in the number of publications on the topic in the last decade, with a growing emphasis on the impact of artificial intelligence and online education on the motivation and development of socio-emotional skills in gifted students.

The sample represents data extracted from 18 countries. Obtaining data from different cultural contexts or countries allows for analyzing current approaches that incorporate new technologies in curriculum design from a global perspective and highlighting common challenges experienced by the gifted population. The analyzed studies mainly come from Asia, Europe, and North America. Collaboration networks are identified among authors from countries such as South Korea, Spain, Turkey, and the U.S. However, there is low interconnection between research from different regions, suggesting opportunities to strengthen international cooperation in analyzing these effects.

56% of the studies employed a quantitative research design, 22% qualitative, and 22% mixed methods. Combining quantitative and qualitative data is useful for evaluating the effects of technological interventions on the attitudes and skills of gifted students, where experimental trials should be complemented with other sources of empirical evidence, such as the practical experience of professionals or feedback from practice recipients. However, the exploratory and non-generalizable nature of the included descriptive studies limits the conclusions.

The set of qualitative and quantitative research analyzed suggests that after the implementation of new technologies in the educational system, there may be undesirable effects on the development of 21st-century skills. These effects are mainly a limited development of creative, collaborative, and interpersonal skills, demotivation for learning, and inadequate and irresponsible use of new technologies. 78% of the effects are related to the orientation of curricula towards standardized tests and 64% to the lack of teacher motivation and competence. The results are discussed based on the skills suggested by the OECD (2019) for high-quality education: innovation and creativity skills, technological skills, interpersonal skills, collaborative and problem-based learning skills, lifelong and student-driven learning skills, and global citizenship and ethical and responsible use of new technologies.

Discussion

Innovation and Creativity Skills

Research has shown that when gifted students participate in robotics and AI interventions, they consistently show improvements in creative thinking (fluency, flexibility, elaboration, and originality) (Abu Owda et al., 2023; Babaoglu & Güven Yildirim, 2023; Jamali, 2019). These students not only seek novel and complex ideas but also want to express their own ideas in unique and elaborate ways through technology. They prefer to build new knowledge and applications rather than being mere consumers of content. However, an appropriate climate is necessary for the expression of creative attitudes (Jamali, 2019).

In STEM education, gifted students reported that memorization, lack of interdisciplinarity, and the structuring and control of content inhibited creative production (Hinterplattner et al., 2022; Mullet et al., 2018). Additionally, some teachers had a negative view of creative students, which affected grade assignment (Maker, 2020).

In the regular classroom context, Jamali (2019) found that gifted students who had participated in a robotics program did not significantly improve in originality. In mathematical creativity tests with multimedia tools, Manuel and Freiman (2017) found that gifted adolescents tended to create closed, single-answer problems similar to those used in classrooms, rather than using open, multiple-answer problems (associated with creative thinking). Similarly, Salazar Tornel et al. (2022) observed that gifted high school students tended to reproduce test examples and repeatedly apply the same algorithm or sequence of algorithms, rather than using creative response strategies. In this regard, a negative correlation has been found between the creativity of gifted students and academic performance (Zbainos & Beloyianni, 2018). Furthermore, it has been found that the creativity of gifted students changes, with a decreasing trend, as they progress through the school system (Sastre-Riba & Pascual-Sufrate, 2013). The authors argue that the creativity of gifted students may be compromised by an educational system that promotes convergent learning at the expense of divergent/creative learning (Manuel & Freiman, 2017; Salazar Tornel et al., 2022; Sastre-Riba & Pascual-Sufrate, 2013). This would explain why the scores obtained by 81 countries in the PISA (Programme for International Student Assessment) academic performance tests do not correlate with national innovation measures, including patents per capita and Nobel Prizes (Kim & Coxon, 2016).

As a result, many students who exhibit intellectual curiosity and creative problem-solving talents may go unnoticed, not be recognized by their teachers, and therefore receive insufficient support as their education progresses. Some will not develop their potential, while others, demotivated by the school system, will be forced to make discoveries on their own, far from the academic environment (Steenbergen-Hu et al., 2020).

Technological Skills

Research has shown that gifted students who participate in robotics and AI projects not only improve their technological skills, including self-regulation and deep learning strategies, but also their computational thinking, research, and innovation skills (Abu Owda et al., 2023; Choi & Hong, 2015; Siegle, 2023).

However, there is still little consensus on a formal definition of computational thinking and how to integrate, measure, and evaluate it in educational curricula. Choi and Lee (2015) found that the deep learning strategy scores of 249 gifted students obtained through an intelligent tutoring system were not related to the grades obtained in concept learning and academic performance. In an enrichment program for gifted students where advanced technology played a significant role, García-Perales and Almeida (2019) observed an improvement in adaptation scores, but less than half of the students improved their academic performance. Moreover, talent development experts argue that some gifted students may have had very good academic performance without using technological skills, due to a combination of their high abilities and an unchallenging curriculum. Conversely, others may have achieved high levels of self-regulation and deep learning strategy management and gone unnoticed by an evaluation method that does not consider such skills (Steenbergen-Hu et al., 2020). This questions the validity of academic grades in measuring higher-order thinking skills and deep learning strategies, which promote computational thinking and the ethical and responsible use of AI tools.

Furthermore, there is a limited number of studies introducing computational thinking and robotics skills into educational practice. One of the main reasons is that teachers still have an unclear and practical pedagogical orientation of computational thinking, reducing it to programming language (Anisimova et al., 2017; Çakır et al., 2021). As a result, they do not integrate the coding environment into an attractive context for gifted students, reducing interest and motivation for programming and causing them to make little use of these skills in other disciplines and personal projects (Çakır et al., 2021). Similarly, although scientific and technological knowledge has the capacity to apply AI in basic education, teachers are barely integrating AI tools into the classroom (Lee et al., 2024). Factors limiting their acceptance include teachers' perception of lack of utility, difficulty of use, and distrust.

The use of AI tools, such as ChatGPT, has raised concerns about their influence on student cheating behaviors, as they might pass off AI-generated texts as their own. However, recent research (Lee et al., 2024) has shown that the percentage of high school students who reported engaging in cheating behaviors in 2023, specifically between 60% and 70%, is the same as many years before the launch and public awareness of ChatGPT and other generative AI technologies. This suggests that cheating in academia likely responds to a more complex systemic problem.

The low level of knowledge of educational technologies for the development of giftedness among science and technology teachers leads to a decline and fading of creative activity among these students (AlAli et al., 2024; Anisimova et al., 2017; Ayık & Gül, 2025). A significant percentage of teachers report not having received training on giftedness during their careers, and those who have received it declare not feeling prepared and motivated to work with these students (Anisimova et al., 2017; Kunt & Tortop, 2017; Opoku et al., 2025; Sandri, 2023; Yıldırım et al., 2024), making it difficult to implement AI projects in their curricula (Öztüre Yavuz et al., 2024).

Additionally, the integration of new technologies in education requires training resources, technology, and continuous support. Disparities in resources, both technological and financial, can create barriers for some schools and students. The implementation of technologies such as robotics and AI in well-funded schools may surpass that of less privileged institutions, exacerbating existing educational inequalities. Similarly, there is a clear risk of social lag in countries that do not invest in technology education (Mun et al., 2020). Such an impact may cause technological delays that will affect the achievement of the OECD's objectives (OECD, 2019). Therefore, ensuring equitable access to education in new technologies poses a significant challenge.

Interpersonal Skills

Research has shown that gifted students possess characteristics that are considered valuable for maintaining competent social interactions, such as developed linguistic and communication skills, emotional sensitivity, and a high level of moral reasoning (Guthrie, 2019). Additionally, the interactive and practical nature of artificial agents and virtual reality experiences support these skills (Gómez-León, 2022; Sarıca et al., 2024; Yavuz & Usluel, 2024). However, a conducive environment must be ensured to develop these socio-emotional competencies. Mullet et al. (2018) found that gifted students refrained from speaking and participating in STEM classes to avoid ridicule from their peers. In Miedijensky's (2018) study, 83% of teachers recognized that these students experienced stressful situations in the classroom, were often excluded by their peers, and felt that school was not the right place for them, which reduced, among other skills, their creative expressions.

In the online learning context, it has been found that the social environment with like-minded intellectual peers is the most important factor in increasing the satisfaction and engagement of gifted students. However, there is a widespread complaint about the lack of opportunities for socialization through social tools (Aboud, 2021; Alshehri, 2022; Potts, 2019; Sandri et al., 2023; Wolfgang & Snyderman, 2022). Additionally, students encounter some communication challenges, such as lack of fluency in dialogue, which disrupts the flow of ideas, and difficulties in interpreting texts related to emotions, humor, or sarcasm (Potts, 2019).

The increase in the number of students using smartphones, as well as the time spent on the Internet, has been accompanied by an increase in online bullying or cyberbullying (Dominguez-Vergara et al., 2023). Specifically, in Spain, 31.6% of gifted students aged 10 to 14 are victims of cyberbullying, a higher percentage than the general population, and these figures increase with age, peaking between 14 and 16 years (González-Cabrera et al., 2019). As a result, these students show symptoms of depression and anxiety, lower engagement with learning, and poorer academic performance (Öztüre Yavuz et al., 2024). Additionally, although the percentage of gifted students who admit to being cyberbullies is lower than the general population (González-Cabrera et al., 2019), it has been found that when they participate in cyberbullying, they are more creative and use a wider variety of techniques to do so (Siegle, 2017). These prevalence rates reveal a situation that requires special attention from teachers. However, Wolfgang and Snyderman (2022) found that 60% of parents of gifted students stated that their children's socio-emotional needs were not being met. Moreover, stereotypes about the socio-emotional maladjustment of gifted students lead to negative attitudes from teachers and lower motivation to participate in their learning processes (Matheis et al., 2017). The lack of support and the cold and dismissive attitude of some teachers cause some students to refuse to participate in STEM projects over time (Mullet et al., 2018).

Despite unanimous agreement among teachers that gifted students need a safe environment that ensures calm and emotional stability (Miedijensky, 2018), the evaluation of emotional and interpersonal skills in educational practice remains incipient. For example, according to OECD data (2024), only two countries, Colombia and Japan, collect information on social and emotional skills as part of their national assessment in the first stage of secondary education.

Collaborative and Problem-Based Learning Skills

One of the objectives of STEAM education is to teach concepts and uses of technology within an interesting and motivating context that fosters teamwork and stimulates students' autonomy in problem-solving. Research has shown that in collaborative STEAM activities, gifted students are open to holding different viewpoints with their peers, listening to proposals and ideas, and rethinking their own perspectives, so they can easily assume leadership roles (Sarıca et al., 2024). Moreover, these students prefer collaborative work over individual work when it is shared equitably, the task can benefit from combined effort, and the environment provides social and cognitive support. However, in STEM educational practice, many gifted students describe negative experiences, such as the lack of teacher control and supervision (Mullet et al., 2018) and the need to take responsibility and complete projects alone, with little or no collaboration among their peers, to ensure high grades (Lee et al., 2015). This suggests that in regular classrooms, only the product of individual achievement might be evaluated instead of the collaborative process.

On the other hand, despite the great potential of distance education for collaborative work (Tusyanah et al., 2023), gifted students miss engaging in such activities with other students who share their interests (Aboud, 2021; Alshehri, 2022; Potts, 2019; Sandri et al., 2023; Wolfgang & Snyderman, 2022). For example, in Sandri et al.'s (2023) study, only 13% of teachers conducted collaborative activities.

Although STEM education standards recommend an active, student-centered, and research-based learning approach, gifted students report that standardized assessment tests negatively drive instruction, content decisions, and overall classroom experiences (Hinterplattner et al., 2019; Ismail et al., 2022; Mullet et al., 2018; Tofel-Grehl et al., 2018). After analyzing five STEM schools specialized in gifted students, Tofel-Grehl et al. (2018) found that many students perceived that the endless cycle of tests prevented them from accessing the knowledge they were interested in and dedicating their time to what they wanted to learn, thus excluding meaningful learning. Often, teachers instructed students to learn the content independently, and some refused to respond: " That won't be on the Advanced Placement so I don't cover it. Figure it out." (p.135). As a result, students experienced classes with anxiety, writing problems at a fast pace, while spending nights trying to learn the content through chat rooms without really knowing "why."

This data becomes more relevant considering that standardized tests only measure a small part of the performance of exceptionally talented students in STEM disciplines (Maker, 2020). For example, visuospatial ability is a better predictor of success in these disciplines than mathematical and verbal reasoning, yet it is not considered in the educational environment. This contributes to many students with exceptional abilities in these disciplines going unnoticed (Maker, 2020). Additionally, given the gender gap in the spatial ability of gifted students (Coxon, 2012), neglecting early education in this skill can contribute to perpetuating gender disparities in STEM fields. In fact, in Mullet et al.'s (2018) study, only one of the five women who had participated in the STEM methodology in secondary school chose a university career specialized in these disciplines.

Lifelong and Student-Driven Learning Skills

Research has shown that one of the characteristics predicting the level of engagement of gifted students in technological activities is their approach to deep and surface learning (Öztüre Yavuz et al., 2024). Deep learning is driven by intrinsic motivation and task mastery orientation. When gifted students participate in activities involving the use of new technologies, such as robotics and AI, they show strong intrinsic motivation for learning and use deep learning strategies (higher-order, comprehensive, and reflective strategies) (Öztüre Yavuz et al., 2024; Steenbergen-Hu et al., 2020). Therefore, they are usually more interested in enhancing their skills, mastering content, and creating new applications rather than relying on them (Manuel & Freiman, 2017).

However, it has been found that students' perceptions of assessment methods significantly influence their learning and study approaches. Kazemi and Sayyadi (2014) found that the level of intrinsic motivation for learning among gifted technology students significantly decreased in the two years preceding university entrance exams. Similarly, in a sample of gifted adolescents, Garrett and Moltzen (2011) found that as they progressed through the school system, students felt that the nature of the curriculum and assessment practices increasingly threatened their intrinsic motivation for learning and decreased the satisfaction they derived from practicing their skills at school. In the context of problem-based learning, Choi and Lee (2015) found that the engagement and intrinsic motivation of gifted students decreased when they perceived that an intelligent tutor focused the learning content on academic grades and immediate assessment, reducing the use of deep learning strategies.

Another factor that strongly impacts the academic attitudes and behaviors of gifted students is the teacher's ability to adapt content to their learning needs. While online instruction has great potential to meet the needs of gifted students, it has been found that the lack of autonomy, challenge, and enrichment provided by regular education teachers in distance education reduces student engagement and motivation (Aboud, 2021; Alshehri, 2022; Sandri et al., 2023; Wolfgang & Snyderman, 2022). In Aboud's (2021) study, 66% of parents suggested that if teachers were trained to use technology, online learning would be of much higher quality.

In the regular classroom, gifted STEM students feel limited, bored, or wasting time, which fosters inappropriate use of technology, such as writing emails, browsing the Internet, or playing games on their laptops, and reduces their motivation to attend class (Hinterplattner et al., 2022). These students miss authentic learning experiences, opportunities to engage in meaningful research, and greater use of technology for research and simulation rather than relying so much on textbooks (Mullet et al., 2018).

In Mullet et al.'s (2018) study, all students wished that teachers focused less on exam preparation and more on providing intellectual challenges, but the challenge in the classroom translated into heavy workloads and fast pace, rather than complexity and critical thinking. Similarly, Tofel-Grehl et al. (2018) found that some teachers' strategies in the classroom reduced students' intrinsic motivation for learning. For example, in a STEM school specialized in gifted students, a teacher posted students' exam results over 10 years on the wall. When asked about it, she explained: " All my kids get fives on that test. Well, except this one student who got a four." (Tofel-Grehl et al., 2018, p.135). She then pointed to the spot on the wall where she had highlighted that student's score in red. The teacher specified: " I keep these scores up here so they know I care. They are a reflection of me, and I tell them not to embarrass me." (Tofel-Grehl et al., 2018, p.135). Follow-up data showed that students cited fear as their main motivator in class. This data is especially relevant considering that students' self-reported emotions while performing STEM tasks are the most important characteristic for predicting their level of engagement (Öztüre Yavuz et al., 2024; Yavuz & Usluel, 2024).

Global Citizenship and Ethical and Responsible Use of New Technologies

The first recommendation on ethics in AI implementation approved by UNESCO (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2021) highlights the need for professionals to possess ethical, social, and reflective skills to ensure that AI is developed and used for the benefit of humanity and the environment. However, ethical violations in research are an international phenomenon, and more and more AI experts warn of the serious and harmful side effects that result from a lack of ethical reflection when researching, developing, and applying scientific technology, "Isn’t it strange to spend millions to work toward systems that can outsmart us, and then to spend more millions to keep it friendly or controllable?" (Haselager & Mecacci, 2020, p.114).

Research has shown that gifted students score significantly higher in moral reasoning than their average-ability peers (Fabio et al., 2022). In the study by Görgülü and Törün (2025), gifted students mentioned the threats of AI more frequently than its benefits. Among these threats, the most recurrent themes were: loss of control, humans becoming lazy, and malicious use of AI. Moreover, these students express strong concerns that AI could lead to the end of humanity, emphasizing that it must remain under human control and be used ethically. That said, gifted students can also be capable of incredibly destructive and immoral behavior (Fabio et al., 2022; Sternberg & Soleimani Dashtaki, 2024). Therefore, the need to include socio-emotional reflection in the STEM education of gifted students has been emphasized (Gotlieb et al., 2016). Through this type of reflection, students not only project uses of technology that contribute to improving present and future quality of life but also identify with career paths that provide them with the opportunity to contribute satisfactorily to society. However, in educational practice, students barely have time for self-reflection; instead, they must engage in monotonous and repetitive tasks, dedicated to external attention and immediate action (Çakır et al., 2021; Gotlieb et al., 2016; Kocaman, 2023; Kulegel & Topsakal, 2021; Lee & Kim, 2015; Tofel-Grehl et al., 2018). This can undermine the development of a more future-oriented, collaborative, socially responsible technology with a more defined purpose.

Technology has created new opportunities that make fraud more accessible to more students and harder to detect, so gifted students may also be tempted to use their technological skills inappropriately. In the study by Görgülü and Törün (2025), some gifted students admitted to using AI to do their homework, although they acknowledged that when they resorted to this measure, they lost motivation for learning and education felt meaningless. In fact, Yun and Park (2013) found no correlation between the ethical knowledge of gifted science and engineering students and the degree of ethical practice in their projects. Lee and Kim (2015) found that 45% of gifted students violated learning ethics in their projects through behaviors such as cyberplagiarism, false attribution of authorship, falsification, and task transfer, and these behaviors increased with experience, despite these students being aware that they were transgressing academic integrity. Lee et al. (2017) found that educational systems that place more emphasis on the outcome than the process, and do not allow enough time for ethical practice and reflection, increase the risk of gifted students making unethical and irresponsible use of new technologies.

If students perceive that there is little to gain from effort and reflection because the curriculum lacks opportunities for new learning, their skills are not valued, or they experience problems such as frequent bullying or intimidation, they may lose motivation and commitment to learning (Steenbergen-Hu et al., 2020). When students guide their learning by extrinsic motivations, such as submitting academic work and getting a passing grade, they may engage in superficial and passive learning processes and resort to what is most convenient and easy for their interests, such as developing an essay or doing a math exercise using AI tools and applications (Castillejos López, 2022; Choi & Lee, 2015; Morduchowicz, 2023; Sternberg, 2024).

Conclusion

To date, no study has shown that technology replaces the critical or creative capacity of gifted students. Currently, generative AI is replicative; it can recombine and reorder ideas, but it is unclear whether it generates the kind of ideas that can break paradigms, something the world needs to solve the serious problems it faces. Rather, research shows that the creative and socio-moral skills of gifted students can be suppressed by a lack of teacher training and a standardized test-based approach, so students stop being reflective, critical, and creative not because they cannot be, but because they have no incentives to be; as a result, they lose these types of skills and may choose to make unproductive, unethical, and irresponsible use of AI.

A change in educational practices is suggested, moving from focusing exclusively on knowledge transmission and standardized tests to creative exploration and solving real problems with socio-emotional relevance. Additionally, there is a need for teachers who are sufficiently trained and motivated to integrate new technologies into curricula adapted to the needs of gifted students. This way, it could contribute to the formation of students who are not only technologically proficient but also emotionally intelligent and socially competent, prepared to face the complexities of a world where the only constant is change.

Finally, future studies should consider evaluating the unintended effects of interventions as an integral part of research, which would help adapt the use of technology to the populations and contexts in which they are implemented and advance educational practices and policies.

Notes

[1] The references of the articles analyzed in the systematic review can be accessed at the following link: https://data.mendeley.com/preview/4dn5yb4z69?a=37fd0358-92b3-49fb-a6a8-85e588e41758

[2] The methodological characteristics and main results of the analyzed studies can be accessed at the following link: https://data.mendeley.com/preview/4dn5yb4z69?a=37fd0358-92b3-49fb-a6a8-85e588e41758

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