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Evidence of the ISTE Standards for Educators leading to learning gains

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ABSTRACT

The International Society for Technology in Education (ISTE) empirically designed and published educator standards to provide a roadmap for educators on effective technology integration. The purpose of this further study was to determine what empirical evidence demonstrates that the educator practices have a positive impact on student learning. Using a scoping review methodology, a transparent protocol was used for searching, identifying, and selecting articles that map to the practices within the ISTE Standards. The findings of this study reveal that all the practices in ISTE educator standards led to learning gains. This study is important for researchers, practitioners, funders, and policymakers as it provides empirical evidence that the technology practices within the ISTE Standards lead to student learning gains.

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Introduction

Technology has become a common feature of K-12 classrooms (Baker et al., 2019). Educators are using technological tools to improve understanding (Akçayır & Akçayır, 2017), academic achievement (Yilmaz, 2018), and knowledge comprehension (Saltan & Arslan, 2017). Technology is also connected with affective conditions that can improve learning gains, including motivation, attention, and satisfaction toward learning (Ibáñez et al., 2020). Nonetheless, while educational technologies can be used for educational benefits, effectiveness does not come from technology alone but from the strategic matching of the affordances of the technologies to content knowledge and appropriate pedagogies (Koehler & Mishra, 2008). Educators are faced with the challenge of effectively integrate technology into K-12 education to leverage those advantages for learning (Cherner & Mitchell, 2021; Mishra & Koehler, 2007).

Educators leveraging technology are best supported when effective technology integration is clearly defined by a set of comprehensive standards (Dinçer, 2018; Uerz, 2018). Organizations (viz., InTASC, 2013; ISTE, 2017; UNESCO, 2018) have developed standards to be used as guidelines on effectively determining the intersection between content, pedagogies, and technologies. The International Society for Technology in Education (ISTE) developed the first educational technology standards for educators to be developed through research (Crompton & Sykora, 2021). While these standards were developed through an empirical process, educators may not be sure how the practices in the ISTE standards directly tie to a positive impact on learning outcomes. The purpose of this study is to examine extant research evidence matched to the educator practices within the ISTE Standards for Educators to determine the efficacy of those practices.

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Literature review

Educators often lack the knowledge and understanding of how to integrate technology effectively into the curriculum (Spiteri & Chang Rundgren, 2020, Winter et al., 2021). This is further exacerbated by the rapid progression of electronic devices, systems, and resources that can be utilized within education. To integrate technology into learning, educators often use technology to replicate existing teaching strategies rather than maximize the affordances that technologies can provide (Tondeur et al., 2012). For example, instead of paper and pencil worksheets, teachers may create an electronic worksheet that requires students to type the answer into a box instead of writing the answer. This replacement strategy detracts from technology's benefits (Tondeur et al., 2012). Twenty-first-century technologies can go beyond 20th-century teaching approaches, allowing educators to create new forms of learning previously unavailable (Crompton, 2017). One example would be teachers using virtual reality escape rooms for STEM education (Mystakidis & Christopoulos 2022), providing affordances such as immersion, interaction, and imagination (Luo et al., 2021). Scholars (viz., Albion et al., 2015; Dinçer, 2018; Uerz, 2018) posit that with the rapid changes in technology and the lack of educational transformation in using these tools, educators need specific guidance or standards on implementing these technological tools.

Guidance and standards on effectively incorporating technologies into teaching and learning could support educators in promoting more effective use of technology, along with building technological skills, knowledge, and confidence. It is important that good technology-integrated pedagogy is used to significantly improve student academic skills, achievement, and understanding (Akçayır & Akçayır, 2017; Yilmaz, 2018; Saltan & Arslan, 2017). Therefore, it is important to provide guidance for educators on technology integration to foster these positive educational outcomes.

Extant educational technology standards

Within-subject discipline standards, organizations, such as the National Council for the Teachers of English, National Council of Teachers of Mathematics, International Literacy Association, National Council for the Social Studies, and the Teaching English to Speakers of Other Languages, have each provided guidance on the use of technology in teaching and learning. Subject-specific standards can help provide ideas directly connected to the axiomatic systems, concepts, and systems within that subject. However, those directions on the use of technology are broad and overarching and typically do not give explicit comments on what the use of technology looks like in practice. While this guidance may be helpful to educators, more detailed standards will provide supportive direction across subjects.

UNESCO (2018) developed a comprehensive set of standards. UNESCO's (2018) ICT Competency Framework for Teachers is designed to support countries in developing comprehensive educator technology competencies. The six core areas of UNESCO's standards are (1) understanding ICT in education, (2) curriculum and assessment, (3) pedagogy, (4) application of digital skills, (5) organization and administration, and (6) teacher professional learning. These standards were developed by UNESCO, working with technology organizations; CISCO, Intel, ISTE, and Microsoft, and the use of past literature to determine what should be included in the standards. While the UNESCO standards provide an overview, they lack the quality assurance from being developed through a research approach to ensure transparency and minimize bias. Scholars lament that practices used in K-12 schools often appear to be based on current trends or fashions in education and not on evidence based on research (Albion et al., 2015).

Therefore, for this study, the educator section of the ISTE standards was selected. The ISTE educator standards (2017) have detailed standards, and most importantly, the standards were developed through an empirical design-based research process (Crompton & Sykora, 2021). The ISTE standard development included data gathered from focus groups, surveys, and interviews with 2,429 participants encompassing various roles in education. Using a design-based research methodology, the standards were developed through a process of design, implementation, analysis, and revision. A scholarly manuscript of the research process was completed. To further validate the process, the manuscript passed a peer review process to be published in an academic journal in 2021 (Crompton & Sykora, 2021).

Table 1. Educator section of the ISTE standards.

ISTE standard number	Standard title	Standard
2.1	Learner	Educators continually improve their practice by learning from and with others and exploring proven and promising practices that leverage technology to improve student learning.
2.2	Leader	Educators seek out opportunities for leadership to support student empowerment and success and to improve teaching and learning.
2.3	Citizen	Educators inspire students to positively contribute to and responsibly participate in the digital world.
2.4	Collaborator	Educators dedicate time to collaborate with both colleagues and students to improve practice, discover and share resources and ideas, and solve problems.
2.5	Designer	Educators design authentic, learner-driven activities and environments that recognize and accommodate learner variability.
2.6	Facilitator	Educators facilitate learning with technology to support student achievement of the ISTE Standards for Students.
2.7	Analyst	Educators understand and use data to drive their instruction and support students in achieving their learning goals.

From ISTE (2017). ISTE standards for educators. *International Society for Technology in Education*. Retrieved from https://www.iste.org/standards/for-educators.

The complete ISTE Standards (2017) are comprised of five sections: (1) Students, (2) Educators, (3) Education Leaders, (4) Coaches, and (5) Computational Thinking Competencies for Educators. The section titles designate whom those standards are directed toward. The educator section of the ISTE Standards, section two, has seven standards, 2.1 to 2.7. These are listed in Table 1.

Each of these standards is accompanied by three or four indicators that provide further detailed examples of what the standard looks like in practice. The Educator section of the ISTE Standards was developed through a research process with input from 2,429 participants, including association leaders, technology experts, educational leaders, and educators from 38 countries (Crompton & Sykora, 2021). Researchers have used the standards to examine various aspects of using technology for learning. For example, the ISTE Standards were used by Vucaj (2022) to develop a Digital Age Teaching Scale (DATS), and Gomez et al. (2022) used the standards to explore teacher technology integration self-efficacy.

The ISTE Standards have gone through iterations from the original National Education Technology Standards (NETs) in 2000, then NETS in 2008, to the ISTE Standards for Educators in 2017. Across the years, the standards were described as different sets of standards, and in a change in 2021, ISTE now describes one set of standards and sections within the standards related to the role. For example, the educator of the ISTE standards 2.1–2.7. While there are distinct sections of the ISTE Standards, they are all highly interconnected. For example, the Student Section of the ISTE Standards is embedded in the Educator section, with 2.6 requiring educators to "facilitate learning with technology to support student achievement of the ISTE Standards for Students" (ISTE, 2017). While the ISTE Standards were developed through research, further consideration is needed to understand if there is empirical evidence that educator practices are directly tied to positive impacts on student learning.

Purpose

The purpose of this research is to determine if there is extant empirical evidence that the practices within the ISTE Standards for Educators can lead to learning gains. The overarching question is: What empirical evidence demonstrates that the practices in the educator section of the ISTE Standards have a positive impact on student learning?

Method

A scoping review methodology (Peters et al., 2015) has been used to answer the question guiding this study. Scoping reviews map the existing literature of a field in terms of topics and features and determine evidence available on a topic (Peters et al., 2015). As part of the scoping review, an a priori (Stemler, 2001) method was used to provide transparency in how the researchers searched the literature to find the evidence (Moher et al., 2015), including what databases were searched, across what years, and an article inclusion and exclusion criteria.

Search strategy

The search parameters were set from 2015 to 2022. With the rapid changes in technology and pedagogical practices, it was important to ensure that the research used in this review was recent. 2015–2022 allowed for a current review of the last seven years. Following the selection of the years to be included, an electronic search was conducted of educational databases: ERIC, Wiley International, Science Direct, Elsevier Direct, Sage Journals Online, JSTOR, and LearnTechLib. In addition, a hand search was conducted of relevant educational journals from other countries that may not appear in those databases. Three were specifically chosen for this study to help provide a more global perspective: *Information* [journal], *Universal Journal of Educational Research, and Journal Iqra': Study of Education*.

Only peer-reviewed journal articles were selected for further examination to ensure confidence in the quality of the research (Gough et al., 2017). The practices specifically listed in the standard were used as the keywords. In addition to the practices highlighted in the standard, key practices were also included from the standard indicators. The standard indicators are extra descriptive text that provides examples of what the standard would look like in practice. To ensure consistency between the keywords chosen for the search and the ISTE standards, the Senior Director of the ISTE Standards provided input and confirmed the final selection of keywords. That confirmed list of keywords is found in Table 2.

The keywords were used in conjunction with the terms "K-12 Education," "Technology," and "Student Learning" to ensure the database search findings included those aspects required of the study. The Boolean String used in this study was:

[keyword] AND K-12 OR K12 AND Technology AND "Student Learning"

Aligned with the methodology of a scoping review, to examine multiple topics, individual searches were conducted for each of the practices, using the keywords to identify examples of the use of those practices within the research.

Inclusion and exclusion criteria

Once the search retrieved a list of findings, each article was then examined against inclusion and exclusion criteria, starting from the top of the returned list, see Table 3.

These articles aligned to the inclusion and exclusion criteria were then reviewed again to find one to two examples for each practice described within a standard. Articles were then prioritized for selection by a representative match to the research question, then by the most recent publication date, and finally, ensuring a spread across disciplines and learner age. A representative match is that it maps (Peters et al., 2015) to the practice described in the ISTE standard.

Findings

The findings section is organized by the key practices identified from the ISTE Standards. The keywords are used as the subheadings. These subsections begin with up-to-date literature focused on aspects of the highlighted practice. Then, from the scoping review findings, one to two articles that embody that practice and provide evidence of increased student learning are reported.

Learner 2.1

From the learner standard, key attributes in the language of the standard connected to professional development, educator use of research best practices, reflecting, and exploring promising practices.

Table 2. Keywords connected with the educator standards.

ISTE standard number	Standard title	Standard	Keywords
2.1	Learner	Educators continually improve their practice by learning from and with others and exploring proven and promising practices that leverage technology to improve student learning.	Professional development Teachers using best practices Teacher reflection
2.2	Leader	Educators seek out opportunities for leadership to support student empowerment and success and to improve teaching and learning.	Teacher leadership, advocate, modeling. Student empowerment
2.3	Citizen	Educators inspire students to positively contribute to and responsibly participate in the digital world.	Digital citizenship Critical evaluation
2.4	Collaborator	Educators dedicate time to collaborate with both colleagues and students to improve practice, discover and share resources and ideas, and solve problems.	Teacher collaboration Student-to-teacher collaboration Real-world experts
2.5	Designer	Educators design authentic, learner-driven activities and environments that recognize and accommodate learner variability.	Authentic learning Student-centered Learner variability
2.6	Facilitator	Educators facilitate learning with technology to support student achievement of the ISTE Standards for Students.	Student ownership of learning Computational/design thinking
2.7	Analyst	Educators understand and use data to drive their instruction and support students in achieving their learning goals.	Alternative assessment Data-driven instruction Authentic learning

Professional development

This standard explicitly indicates the need for educators to continually improve their practice. The global need for educator professional development is well recognized across subjects and grade levels as a driving force to improve student learning (Bold et al., 2017; Popova et al., 2022). Educators exposed to quality professional development will most likely improve their teaching abilities (K. Xie et al., 2019), leading to improved student learning outcomes. With continual technological changes and the concomitant new pedagogical affordances available, professional development in effective technology integration is paramount (Cherner & Mitchell, 2021).

Blanchard et al. (2016) examined if students' mathematics and science assessment scores differed from those who had educators who participated in technology professional development (TPD) and those who did not. In this mixed-methods, three-year study, 20 educators in two schools in neighboring rural, high-poverty school districts took part with 2,230 students. Teachers learned to integrate technologies into their teaching in professions development across three summers and throughout the school year. All educators in the study used technology, but the findings show that when comparing student learning gains in classrooms with educators who received technology, professional development had higher learning gains than those that had not. Indeed, the African American students that comprised 67% of the study participants showed significant gains in end-of-grade mathematics and science tests. Furthermore, for each additional TPD educator a student had, that student's mathematics score increased by 0.07 levels and science score increased by 0.08 on the end of grade tests.

Research best practices

As educators connect with "proven practices," the evidence for those practices comes from research. While universities should incorporate research-based best practices in pre-service teacher training, this is not always effective. From teacher interviews and thematic analysis, Jakhelln et al. (2021) found only a weak connection between research knowledge gained in pre-service training and the teachers' professional work. Darling-Hammond (2017) posited that a research-based education is needed to drive change and development.

Table 3. Inclusion/exclusion criteria.

Inclusion	Exclusion
• Include the K-12 context • Focused on formal education • Peer-reviewed • Journal articles • Focused on the use of technology for learning • Studies published between 2015–2022	Conference proceedings Articles not published in English

In a recent study, Maruf et al. (2022) reviewed extant research examining best instructional practices on student learning outcomes. This study focused on best practices in virtual learning applications. From examining the data, the researchers found that teaching innovations that use best practices led to improved learning outcomes. The authors note that using technologies with best practices in learning has accelerated students learning through flexible solutions and innovations. Albion et al. (2015) also studied teachers' professional development for technology integration and the relationship between research and practice. The researchers explored case studies from Australia, Vietnam, Israel, and Belgium and found that positive educators' practice with technology was closely related to teacher use of educational research. This is important as research shows that positive practices with technology lead to higher student learning outcomes and improved overall academic standards (see Sarkar et al., 2017).

Exploring promising practices

Exploring promising practices has educators going beyond their typical pedagogical approaches to explore new approaches that can further enhance learning gains. However, due to challenges faced by educators while integrating technology (Cherner & Mitchell, 2021; Mishra & Koehler, 2007) and some educator's beliefs that education should retain past pedagogical practices, many are nervous about trying out new practices (Scharber et al., 2021). However, new strategies must be embraced to encourage creativity and transformative teaching practices (Henriksen et al., 2019) that can lead to learning gains.

In a study of innovative digital learning practices, Lin et al. (2017) studied the effect on learning outcomes. In this mixed methods study, with 116 students across four classes, two classes (58 students) were the experimental group exploring innovative teaching approaches with technology, and the other students in the control group had a traditional teaching approach to lectures. The findings reveal a significant difference in learning gains, higher than traditional teaching. Furthermore, the findings also showed that innovative learning approaches had a better positive effect on learning motivation than traditional teaching and that learning motivation positively affected learning gains.

Leader 2.2

Within the leader standard 2.2, the key practices focus on educators as leaders for student empowerment and success.

Teacher leaders improving learning

As described in the ISTE standard, leadership is not necessarily focused on those appointed to a formal leadership role but on informal leadership of those technology champions supporting colleagues. Educators acting as leaders are recognized and valued for promoting educational reform (Stein et al., 2016). A systematic review examining 40 independent research studies found that bottom-up development initiatives were more beneficial to educators than top-down (Vangrieken et al., 2017). Vangrieken and colleagues found that top-down approaches followed a specific time frame and agenda. At the same time, educator-led development initiatives were deemed more desirable and relevant as they focused on current problems in practice. Educator leadership also led to educator improvements in learning that can lead to improved student learning outcomes.

Sebastian et al. (2017) examined the roles of leadership pathways in high schools, including direct and indirect leadership pathways to student achievement growth. The main finding in the study was that teacher leadership played a key mediating role between principal leadership and student achievement *via* the school learning climate. The scholars report that principals are no longer perceived as the sole source of leadership, and educators seek leadership from peers to improve learning gains. Sebastian's study data included English, mathematics, science, and reading tests from 191,826 high school students. The findings show that the addition of teacher leaders working with principals leads to student learning gains and teacher leadership should be encouraged. Educators can be leaders in technology by sharing strategies, tools, techniques, and tip, with other educators, individually, among teams, in school-wide presentations, at conferences, and in online forums.

Empowering students

Part of educator leadership is sharing that leadership spirit by empowering students. This connects back to Freire's teachings "By sharing power with students, by listening to them …we have learned that educators, researchers, and policymakers are more likely to promote contexts through which the voiceless have a voice, the powerless have power and from such spaces, hope can emerge (Freire, 1994, p. 491). There is a plethora of technologies that can empower students and give them a voice and choice (Blau & Shamir-Inbal, 2018).

Empowering students using technology leads to knowledge gains beyond traditional approaches (Stojanović et al., 2023). In the aptly named study "empowering learning process in secondary education using pervasive technologies," Stojanović and colleagues used mobile devices and the Internet of Things (IoT). The students listened to a lecture and then took an economics test. The experimental group used a mobile platform and IoT tools, and the control group solved test items using a traditional approach. The findings show a statistically significant difference (t (37) = 4.86, with $p < 0.05$) with the empowered technology students outperforming the traditional group. In another study, Franklin et al. (2020) had 536 students (ages 9–14, grades 4–8) working within a Scratch-based curriculum, Scratch Encore. The findings reveal that the activities led to learning gains as technology was used to empower students.

Citizen 2.3

The Citizen Standard 2.3 standard has educators preparing students to contribute positively to the digital world and behave responsibly. Having students become good digital citizens involves cognitive factors (e.g., critical thinking ability, communication ability, autonomous judgment ability, and rational decision-making ability), emotional factors (e.g., human dignity, tolerance, community consciousness, responsibility, and care), and behavioral factors (e.g., active participation, autonomous regulation, compliance with laws and regulations) (Kim & Choi, 2018). These attributes are described in the educator standards and the student section of the ISTE Standards.

Cognitive factors

Building students' knowledge and skills to become good digital citizens requires students to develop cognitive skills and strategies (Kim & Choi, 2018). Research evidence shows that critical thinking skills increase learning gains across subjects such as mathematics (Alcantara et al., 2017), science (Saputri et al., 2019), and language learning (Heidari, 2020). Digital environments, such as the Internet, provide a real-world context for developing these skills that can be used in other aspects of learning and the workplace (Gazi, 2016). The indicators for standard 2.3 state that educators should prepare students to examine online resources critically.

In a study involving 185 high school students, researchers found that students overestimate their critical thinking skills (Petrucco & Agostini, 2020). The scholars noted that students are widely exposed to information flows from old and new media, making fact-checking difficult but essential. Sung, Hwang, and Chang (2015) studied how students used the Internet to find resources. In this comparison study, the experimental group used technology with a structured pedagogical approach to encourage critical thinking, and the control group used technology, but the Internet searching was unstructured. The findings showed that the experimental group had significantly higher learning achievement and higher levels of critical thinking than the control group. Furthermore, students' attitudes toward learning were significantly higher in the experimental group. It appears that higher learning gains are not only achieved by students using technology but by the technology used in conjunction with good pedagogical practices. In this case, students were developing critical thinking skills with technology.

Emotional factors

Building empathy and social responsibility are highlighted in the ISTE Standards and indicators. Social media websites, programs, and applications mainly focus on human and content interaction and sharing. Interactive environments and social media provide opportunities for students to connect and engage when coupled with educator best practices (Greenhow et al., 2020). By using social media, educators have facilitated students' relationship-building with local classmates (Schwarz & Caduri, 2016) and with other students worldwide (Carpenter & Justice, 2018). The research highlights various benefits to learning with social media, including student engagement, improving educator-student relationships, organization, and learning gains (Asterhan & Rosenberg, 2015; Greenhow et al., 2020).

A study by Chapman and Marich (2021) investigated how teachers used the social media platform Twitter to teach civic knowledge and skills in both elementary and high school. Twitter was a useful platform for learning about safe online practices and developing digital citizenship skills. Findings from Chapman and Marich's study of the elementary years show that point of view and perspective, appropriate interactions, and effective communication skills prepared the students for learning about social justice and political activism in high school. In high school, the findings revealed benefits to learning in the ability to apply knowledge, information, and skills in the digital space as well as the physical space, critical thinking in understanding fake news, and how social media is used for both communication and propaganda, how to interact with a diverse array of viewpoints, awareness of current events, and the opportunity to engage in civic actions while practicing skills that would allow students to be lifelong engaged citizens.

Behavioral factors

Behavioral factors focus on the legal, ethical, and safe aspects of using and interacting with people and content on the Internet. Having students understand these key Internet aspects is important as students use the Internet, especially with the rise of 1:1 devices and students' independent use of the Internet in learning (Moon, 2018). Tapingkae et al. (2020) had 115 seventh and eighth-grade students working through scenarios in a digital game-based learning environment. The scenario covered digital ethics and safety aspects, such as learning how to recognize and respond to risky online interactions. The games allow students to practice good behavior in a safe environment. The quasi-experimental study compared the experimental group of students learning through a game-based environment of the app and the control group who covered the same content while learning through a traditional "chalk and talk" activity. The findings revealed that the experimental group achieved significantly better scores on digital citizenship than the control group. Furthermore, that understanding led to decreased concerns about online harassment, victimization, and perpetration behaviors as students had increased levels of understanding of how to avoid and safely navigate those negative situations.

Collaborator 2.4

One of the major attributes of technologies is how they can facilitate communication and collaboration. The extent of this affordance was particularly highlighted during the COVID-19 pandemic, as often the only method of communication and working together was through technology (Crompton et al., 2022). The benefits of collaboration have been documented well before the pandemic, with research showing that educator collaboration increased pedagogical and disciplinary content knowledge and focus on student learning (Dogan et al., 2016).

Teacher collaboration

Akiba and Liang (2017) conducted a longitudinal survey of 467 middle school mathematics teachers in 91 schools to examine teacher practices and student learning. *via* a survey, these educators were asked to report on various teaching practices. This included documenting their collaborative activities and the number of hours involved with those collaborations. The findings revealed that educator collaborative activities were more effective in improving student achievement than learning activities not involving teacher collaboration. Furthermore, the findings from this study show that teachers collaborating through presenting and participation at conferences were also associated with student achievement growth in mathematics.

Teacher and student collaboration

Ronfeldt et al. (2015) had similar findings of educator collaboration connected with student academic growth. The study involved 9,000 educators and examined the relationship between collaboration and student achievement in reading and mathematics. The study focused on educator-to-educator as well as educator-to-student collaborations. The statistical findings show that collaboration significantly predicted student achievement in reading and mathematics. These researchers noted that the purpose and quality of the collaboration were important. These tie to ISTE Standard 2.4 as it delineates collaborative practices to improve practice, discover and share resources and ideas, and solve problems.

Authentic learning collaborating with experts

In addition to highlighting those collaborations between educators and educators with students when using technology, the indicators for ISTE Standard 2.4 also describe the importance of providing students opportunities to work with real-world experts. Having K-12 students work with real-world experts has been well documented, with scholars reporting various positive gains for student learning. Indeed, an examination using Maude's (2018) development of knowledge (Healey & Walshe, 2020) delineates how working with real-world experts on technological tools supported students in developing (1) new ways of thinking about the subject content, (2) knowledge that provides students with powerful ways of analyzing, explaining and understanding, (3) knowledge that gives students power over their own knowledge, (4) the ability to follow and participate in debates on significant local, national and global issues, and (5) knowledge of the world.

In working with high school geography students, Healey and Walshe (2020) conducted a study to explore how using real-world geography experts might support students' geographical knowledge. In this study, students and experts used a Geographical Information System (GIS) platform. Across a year, students were introduced to GIS using various approaches to working with real-world geographers. Students studied topics such as the predictability of storm hazard events. Experts shared real-world accounts of how they used the tools and why they were important in their work. From this longitudinal study, the results concluded that engagement with industry experts can aid in students' understanding of what GIS is. They allowed students to develop a more nuanced appreciation of the discipline. Most importantly, the use of real-world experts and technology played a direct and indirect role in developing students' geographical knowledge.

Healey and Walshe (2020) make an important note in the findings that "the teacher acting as an intermediary between real-world experts and students is crucial to ensuring that real-world experts can be leveraged effectively to support the development of geographical knowledge" (p. 193). Aligned to ISTE Standard 2.4, the educator's role is to not just provide opportunities for students to collaborate with real-world experts but purposefully design and facilitate those collaborations.

Designer 2.5

ISTE Standard 2.5 designer is focused on the pre-planning of learning. While this standard is multi-faceted, three parts are highlighted in the standard statement: (1) authentic activities, (2) learner-driven, and (3) accommodating learner variability.

Authentic learning

There is a plethora of extant empirical studies revealing the benefits of using technologies with an authentic approach to learning. The contextual learning approach effectively ensures students learn with a more meaningful understanding of the content through actual practice with authentic problems. It facilitates students' participation in authentic learning activities and reinforces their learning performance with the benefits of technologies (Hwang et al., 2015; Sung, Hwang, & Yen, 2015; Tapingkae et al., 2020).

In a recent study, Aynas and Aslan (2021) examined how authentic learning practices with technology supported academic success in science. With 92 participants, a quasi-experimental design was used with pretest and post-test control groups. The researchers had students focus on "systems in our bodies" and used authentic problems that students could connect to in their own lives. Students used Internet sources to examine different perspectives. The researchers found a significant difference between the experimental and control groups regarding academic success and "permanency" in knowledge retention.

Student-centered

The indicators highlight that the student-centered focus should be on personalizing the learning experiences. Scholars (viz., Ornstein & Hunkins, 2016) lament that education should be more aligned with students and more consistent with their interests so they gain a sense of power, fulfillment, and importance in the classroom to ensure learning. Technology has been used to personalize learning by allowing learners to meet their learning goals through tools that promote awareness, self-reflection, assessment, feedback, and motivation (Chatti & Muslim, 2019).

H. Xie et al. (2019) reviewed technology-enhanced personalized learning across 60 empirical studies. In examining learning outcomes, the data show that 61.4% focused on learning gains from using the personalized technology approach. Of the 60 studies, educators and researchers reported improved learning gains using technology to personalize learning through interfaces, learning contents, learning paths, diagnosis and suggestions, recommendations, prompts and feedback, and guidance. For example, Huang et al. (2016) developed a personalized mobile vocabulary learning system for language learners to examine learning gains. The experimental results of this study revealed that the learning gains of the experimental group of students who

Table 4. Research studies identified as evidence of the ISTE standards.

ISTE standard	Authors	Year	Article title	Discipline	Student grade level
2.1 Learner					
Professional development	Blanchard et al.	2016	Investigating technology-enhanced teacher professional development in rural, high-poverty middle schools.	Math and Science	Middle
Research best practices	Maruf et al.	2022	Virtual learning apps: Best instructional leadership practices in the digital age efforts to improve student learning outcomes	Various	Varous
Exploring promising practices	Lin et al.	2017	A study of the effects of digital learning on learning motivation and learning outcome.	IT	Middle/ High
2.2 Leader					
Teacher leaders	Sebastian et al.	2017	Examining integrated leadership systems in high schools: connecting principal and teacher leadership to organizational processes and student outcomes.	English, mathematics, science, and reading	High
Empowering students	Stojanović et al.	2020	Empowering learning process in secondary education using pervasive technologies.	Economics	Middle/ High
2.3 Citizen					
Cognitive factors	Alcantara et al.	2017	Critical Thinking and Problem-Solving Skills in Mathematics of Grade-7 Public Secondary Students.	Math	Middle/ High
Emotional factors	Chapman and Marich	2021	Using Twitter for Civic Education in K-12 Classrooms.	Civic Education	K-12
Behavioral factors	Tapingkae et al.	2020	Effects of a formative assessment-based contextual gaming approach on students' digital citizenship behaviors, learning motivations, and perceptions.	Digital Citizenship	Middle/ High
2.3 Citizen					
Teacher collaboration	Akiba & Liang	2017	Effects of teacher professional characteristics on student achievement.	Math	Middle
Teacher and student collaboration	Ronfeldt et al	2015	Teacher collaboration in instructional teams and student achievement.	Reading and Math	All
Student and expert collaboration	Healey & Walshe	2020	Real-world geographers and geography students using GIS: relevance, everyday applications and the development of geographical knowledge.	Geography	High
2.5 Designer					
Authentic learning	Aynas & Aslan	2021	The effects of authentic learning practices on academic success in science courses.	Science	Elementary
Student-centered learning	Huang et al.	2016	Effects of situated mobile learning approach on learning motivation and performance of EFL students.	Language	Elementary
Learner variability	Fernández-Batanero et al.	2022	Assistive technology for the inclusion of students with disabilities: a systematic review.	Various	Various
2.6 Facilitator					
Student Ownership	Song & Wen	2017	Integrating various apps on BYOD (bring your own device) into seamless inquiry-based learning to enhance primary students' science learning.	Science	Elementary
Computational thinking	Aksit & Wiebe	2020	Exploring force and motion concepts in middle grades using computational modeling: A classroom intervention study.	IT	Middle
2.7 Analyst					
Analyst standard	Qian & Lehman	2019	A framework for using hypothesis-driven approaches to support data-driven learning analytics in measuring computational thinking in block-based programming environments.	IT	High
Support students with goals	Kiru et al.	2018	A synthesis of technology-mediated mathematics interventions for Students with or at risk for mathematics learning disabilities.	Various	Various

used the technology system improved significantly more than that of the control group, which adopted the same learning strategy but used conventional learning materials.

Learner variability

Learner variability describes all students who each have a unique set of abilities and experiences. This includes students who have an identified learning difference. It also includes all other students who each have strengths and needs, as well as diverse ways of learning connected with interests, cultural backgrounds, and aspirations. In examining the literature, student-centered and learner variability are highly intertwined. Scholars recognizing learner variability return to the personalized learning approach and focus on the learner. Considering learner variability is important to highlight in the standard as a reminder to educators to consider the needs of all types of students. For example, while Huang et al.'s (2016) personalized mobile vocabulary learning system may provide a bespoke learning experience for many learners, it may not be appropriate for those with physical disabilities who do not learn through the physical manipulation of a mobile device. Fernández-Batanero et al. (2022) examined the use of technologies for the inclusion of students with disabilities. Reviewing 216 studies, the findings show that educators often did not fully consider the different needs of this group of learners. Nonetheless, the findings also revealed a variety of technologies that can be used to provide inclusive learning, such as robots, digital boards, and mobile devices. The aggregated findings show that using technologies increased students' learning gains, social skills, motivation, independence, accessibility, and inclusion.

Facilitator 2.6

Standard 2.6 highlights educator facilitation to ensure students connect with the student standards 1.1–1.7. The indicators were reviewed to parse out key themes to narrow the examination of the research connections. Two themes emerged: student ownership of learning and computational thinking.

Student ownership of learning

Song and Wen (2018) examined learning gains in science from using technology to provide students with ownership of learning. They specifically looked at what mobile device applications promoted learning and how knowledge was advanced using technology. A total of 28 fifth-grade students in Hong Kong were studied across a year-long project. Students studied 12 topics in five science units. Students had access to mobile applications, such as Skitch, Evernote, and Edmodo. Students were also reminded that they could access the camera and recording features on the devices.

The findings of Song and Wen's (2018) study focused on one science unit on plants to further examine the data in detail. The study shows that students chose to use various mobile applications for various purposes. For example, the camera collected data, such as photographs of bean growth. Skitch was often used to annotate photographs. Edmodo was a social network platform for students to share findings, write comments and evaluate their thinking. From the pre- and post-data reflections and knowledge maps, students showed large gains in learning. Students moved beyond basic descriptions of plants. Following the technology-supported activities, students could engage, explore, observe, and explain their inquiry into the structure of the flower and seed, reflect on their inquiry process, and share their inquiry results with peers. The researchers reported that the technologies allowed students to set learning goals and follow their learning pathways. This led to a greater sense of ownership, interest in learning, and advanced learning gains in science.

Computational thinking

Another topic highlighted in standard 2.6 is that educators embed computational thinking into the curriculum. Computational thinking (CT) is the process of thinking and formulating problems so that their solutions can be expressed as computational steps or algorithms to be carried out by a computer (Lee, 2016). Computational thinking can be used as a generalizable skill across disciplines. Aksit and Wiebe (2020) examined using computational models in a block-based programming environment to support the student learning gains in science. The study involved 82 seventh-grade students. Using a mixed methods research design, students used Scratch, a block-based program, to construct simulation-based computational models of scientific phenomena. The findings revealed that students who built the computational models achieved significant conceptual learning gains. The findings show that the dynamic nature of the computational models allowed students to observe and interact with the scientific phenomenon in real-time, and the generative aspect of model construction promoted rich discourse in the classroom facilitating conceptual learning.

Analyst 2.7

ISTE Standard 2.7 highlights the use of data to drive instruction and how educators can support students in achieving their learning goals.

Data-driven instruction

One of the primary affordances of technology is the way technology can use various forms of assessment data to cross-reference, calculate, and provide aggregated information. The extended use of artificial intelligence (AI) in education has greatly advanced the services that technology can provide educators for examining data (Crompton et al., 2022). Data analytics and adaptive learning are two large fields of study involving AI and data-driven instruction. AI can capture learner actions through trace data. These data can then be used to create assessments of those "hard to assess" skills with concepts like abstraction, design, and algorithmic thinking to best measure student skills and understanding (Grover et al., 2017). This information can then be used to guide future learning pathways.

Qian and Lehman (2019) investigated the effects of targeted feedback in an AI-automated assessment system that addressed common misconceptions of high school students in a computer science class. From collecting and examining students' common errors and underlying misconceptions, targeted feedback messages were designed and provided for students. Data from this quantitative study show that learning outcomes were improved. Once the students received the targeted feedback, they were more likely to realize when they had made a mistake, correct it, and remember it for future instances.

Support students in achieving learning goals

The standard indicators provide examples of how educators can support students in achieving their learning goals. These included accommodating learner needs as described in section 2.5 with examples across educational practice. However, this standard, 2.7, provides a more nuanced focus on assessment and meeting all learners where they are, with alternative ways for students to demonstrate competency using technological affordances. Many of these technological approaches provide an engaging, fun, and fast evaluation method that informs instruction and pinpoints areas for further attention and practice during that lesson that may not be possible with traditional assessment approaches.

Kiru et al. (2018) examined extant research on using technology-mediated mathematics for students with or at risk of mathematics learning disabilities. The researchers examined 19 studies, of which nine were single-case, and 10 were group/quasi-experimental designs. Across the studies delineated in Kiru's study, the data show positive learning gains from integrating technology in learning across a wide range of grades and mathematical competencies. The study conclusions highlight that while technology-mediated mathematics had great potential in widely enhancing mathematics instruction to increase student achievement, successful implementation requires technology with instructional practices. In other words, it is not technology alone supporting students, but technology integrated into those practices as outlined in the ISTE standards for educators.

Article summary

To provide the reader with a review of the studies aligned to the ISTE Standards, Table 4 lists the matching articles with details of the empirical work and the participants.

All except three of the studies were primary research in that the researchers conducted those studies. The three studies marked with an asterisk are systematic reviews. Therefore, the evidence came from research findings from across a collection of primary studies.

Limitations and future research

It is important for the reader to note that the ISTE Standards for Educators are multifaceted and this study highlights some of those key aspects of the standards but is not able to provide an in-depth examination of each aspect. For example, Standard 2.6-Facilitator describes adherence to the full set of student standards. As highlighted in the findings, key aspects, such as student ownership of learning and computational thinking were examined but it would be prudent for future research to examine each of these as a standalone study that would provide space for an in-depth examination of each of those practices with technology.

Furthermore, while search parameters ensured the selected articles were of a certain quality, such as quality through a peer review process, published in an academic journal, those parameters may have removed a variety of other examples that may have also fit the ISTE Standards. The reader needs to note that following the methodology, only a few studies were selected for each practice as an example of the evidence and not as an exhaustive list of evidence. This final choice in examples can lead to limitations as some researchers may have chosen different articles to ensure the spread across disciplines and learner age. Also, as part of the inclusion criteria, studies had to be published in English. While a large body of scholarly work is published in English, this may have removed other pertinent articles in other languages. Future researchers may want to widen these parameters to examine other evidence of learning gains mapped to the standards.

Implications

The results of this study have significant implications for education leaders, educators, researchers, practitioners, funders, and policymakers. The ISTE Educator Standards, developed through rigorous research, can be confidently integrated by state and district leaders to improve instruction with technology. Additionally, multiple research studies have validated that these practices lead to student learning gains. Educators can also use the standards as a guide to improve their instruction and help students achieve their learning goals. This study provides valuable evidence for the effectiveness of technology practices, giving confidence to those who use, advocate for, or fund these practices.

Conclusions

The purpose of this study was to determine how the educator section of the ISTE Standards improves learning gains, as confirmed through extant empirical evidence. Aligned with the scoping systematic review methodology, a range of evidence was gathered on each topic (Peters et al., 2015), namely, the ISTE educator standards 2.1–2.7. Following the selection parameters, empirical evidence was mapped to all seven standards of how these specific practices lead to learning gains. In addition to various scholarly work, specific studies were described in further detail about how these practices led to learning gains. From this systematic scoping review, it appears that the educator section of the ISTE Standards has empirical evidence that those practices with technology lead to learning gains in the K-12 context. The research also highlighted that it is not the technology or the pedagogical practice independently fostering those learning gains but the two combined.

Disclosure statement

The author reports that there are no competing interests to declare.

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