TURJE
www.turje.org
2024
Volume: 13 Issue: 1
Turkish Journal of Education
https://doi.org/10.19128/turje.1384524
Review Article
Received 06.11.2023
Accepted 30.12.2023

Teaching socioscientific issues in the digital age: Emerging trends and unexplored frontiers

Dilek Karışan
Adnan Menderes University, Department of Mathematics and Science Education, Aydın, Türkiye, dilekkarisan@gmail.com
Dana L. Zeidler
University of South Florida, Department of Teaching and Learning, Tampa, USA, zeidler@usf.edu

ABSTRACT As society navigates complex socioscientific issues (SSI) in an increasingly digitalized world, science education faces evolving challenges and opportunities. This study aimed to conduct a literature review by systematically analyzing and synthesizing existing research and publications on SSI pedagogy and the digital age. The steps involved in this method include: identifying the research scope, searching and selecting relevant literature, analyzing and synthesizing relevant literature, identifying gaps and trends, and critical evaluation and interpretation. The study explores the intersection of SSI pedagogy and the digital age, shedding light on both emerging trends and uncharted frontiers. The review delves into the dynamic landscape of SSI education, emphasizing the integration of digital technologies as a means to engage students in authentic, real-world problem-solving. It examines the role of technology in enhancing SSI learning experiences, from virtual simulations to online collaborative platforms. Furthermore, the review critically evaluates the impact of digital tools on student decision-making, argumentation skills, and ethical reasoning in the context of socioscientific dilemmas. This review also addresses the challenges and opportunities of teaching SSI in online and blended learning environments, particularly in light of the global shift toward remote education. In summary, this review informs educators, and researchers, and underscores the pivotal role of digital technologies in preparing students to navigate the complex socioscientific challenges of the 21st century.

Keywords: *Digital tools, Online collaborative platforms, Socioscientific issues*

Dijital çağda sosyobilimsel konuların öğretimi: Ortaya çıkan eğilimler ve keşfedilmemiş sınırlar

ÖZ Toplum giderek dijitalleşen bir dünyada karmaşık sosyobilimsel konulara (SBK) yönelirken, fen eğitimi de değişen zorluklar ve fırsatlarla karşı karşıya kalmaktadır. Bu çalışma, SBK ve dijital çağ üzerine mevcut araştırma ve yayınları sistematik bir şekilde analiz ve sentez ederek bir literatür taraması yapmayı amaçlamıştır. Bu yöntemde yer alan adımlar şunlardır: araştırma kapsamının belirlenmesi, ilgili literatürün taranması ve seçilmesi, ilgili literatürün analizi ve sentezlenmesi, boşlukların ve eğilimlerin belirlenmesi ve eleştirel değerlendirme ve yorumlama. Bu literatür incelemesi hem yeni ortaya çıkan trendlere hem de keşfedilmemiş sınırlara ışık tutarak SBK pedagojisi ile dijital çağın kesişimini araştırmaktadır. İnceleme, öğrencileri otantik, gerçek dünya problemlerinin çözümüne dahil etmenin bir yolu olarak dijital teknolojilerin entegrasyonunu vurgulayarak SBK eğitiminin dinamik ortamını araştırmaktadır. Sanal simülasyonlardan çevrimiçi işbirlikçi platformlara kadar teknolojinin SBK öğrenme deneyimlerini geliştirmedeki rolünü incelemektedir. Ayrıca, inceleme, dijital araçların sosyobilimsel ikilemler bağlamında öğrencilerin karar verme, tartışma becerileri ve etik muhakeme üzerindeki etkisini eleştirel bir şekilde değerlendirmektedir. Bu derleme aynı zamanda, özellikle uzaktan eğitime doğru küresel değişim ışığında, çevrimiçi ve karma öğrenme ortamlarında SBK öğretiminin zorluklarını ve fırsatlarını da ele almaktadır. Özetle bu derleme, eğitimcileri ve araştırmacıları bilgilendirmekte ve dijital teknolojilerin öğrencileri 21. yüzyılın karmaşık sosyobilimsel zorluklarının üstesinden gelmeye hazırlamadaki öneminin altını çizmektedir.

Anahtar Sözcükler: *Çevrimiçi işbirlikçi platformlar, Dijital araçlar, Sosyobilimsel konular*

Citation: Karışan, D., & Zeidler, D. L. (2024). Teaching socioscientific issues in the digital age: Emerging trends and unexplored frontiers. *Turkish Journal of Education, 13*(1), 92-109. https://doi.org/10.19128/turje.1384524

INTRODUCTION

In an increasingly digitalized world, as society grapples with complex socioscientific issues (SSI), the realm of education encounters evolving challenges and opportunities. SSI, inherently controversial, necessitates students to apply evidence-based reasoning, holds personal significance for them, and offers a contextual framework for understanding, all while requiring moral judgment and ethical assessment during the decision-making process concerning potential solutions to these issues (Zeidler, 2003). Integrating SSI into science education offers several benefits for both students and society as a whole including relevance to Real-World problems (Karisan & Zeidler, 2017), enhanced critical thinking and problem-solving (Gutierez, 2015), fostering interdisciplinary learning (Johnson et al., 2020), ethical and moral development (Zeidler et al., 2005), effective citizenship education (Chowdhury et al., 2020), heightened cultural and social awareness (Hwang et al., 2023) and improved scientific literacy (Zeidler & Kahn, 2014). There has been a plethora of additional pedagogical, curriculum, and epistemic outcomes and benefits that have been well-documented in reviews of the global extant literature involving hundreds of empirical and conceptual studies that have served as a foundation for the integration of SSI into science education (Zeidler & Sadler, 2023).

However, it is imperative to acknowledge that while SSI integration does face new questions regarding its implementation, as the rapid advancements in digital technology have ushered in a new era of both challenges and creative possibilities. In this digital age, traditional approaches to SSI education are being reshaped, offering emerging trends and unexplored frontiers that demand our attention. Hence, the significance of this review, 'Teaching SSI in the Digital Age: Emerging Trends and Unexplored Frontiers,' becomes apparent. As technology becomes increasingly integrated into education and society at large, we must critically examine how these digital tools and platforms can augment SSI education. This review aims to uncover the latest developments, innovative pedagogical approaches, and technological tools that are reshaping the landscape of SSI education.

By exploring the intersection of SSI pedagogy and the digital age, our review provides valuable insights for educators, researchers, and policymakers. It not only informs the current state of SSI education but also highlights the pressing need to adapt and evolve in response to the opportunities and challenges presented by the digital era. Hence, this review seeks to shed light on the dynamic and ever-evolving landscape of SSI education in the digital age, equipping stakeholders with the knowledge and guidance needed to prepare students for the complex socioscientific challenges of the 21st century.

METHOD

In the review, a literature review was conducted by systematically analyzing and synthesizing the existing research and publications on SSI and the digital age. The steps involved in this methodology are defining the research scope, screening and selecting relevant literature, analyzing and synthesizing relevant literature, identifying gaps and trends, and critical evaluation and interpretation. Firstly, the research scope was determined. The focus of our research is to examine the use of digital tools in SBK teaching. For this purpose, academic databases, Google Scholar, Eric, and Web of Science search engines and indexes were searched to gather information on SSI pedagogy, digital technologies, and their intersection. Specific keywords and criteria were used to select appropriate articles and studies. After collecting the relevant literature, the information from these sources was analyzed and synthesized to provide information about the challenges and opportunities that can be encountered when teaching socioscientific topics with digital tools.

Digital Tools and Platforms for SSI Education

In the digital age, the arsenal of educational resources has expanded significantly, offering an array of

digital tools and platforms that hold immense potential for enhancing SSI education. Digital tools have emerged as invaluable allies in this endeavor, providing educators with innovative means to engage students in meaningful socioscientific discourse and enhance socioscientific reasoning (Elam et al., 2019; Sadler et al., 2011; Zeidler et al., 2019). In this section, we explore the diverse array of digital tools that facilitate the integration of SSI into education (See Figure 1).

Figure 1.
Digital Tools and Platforms for SSI Education

We explore the functionalities and advantages of various educational tools, highlighting specific examples such as Moodle, Google Classroom, and Microsoft Teams in the category of Learning Management Systems; Flip, PhET, Nearpod, Pear Deck, and Kahoot as Interactive Classroom Tools; Zoom and X (Twitter) for Virtual Meetings and Communication; Socrative for Assessment; YouTube and Miro for Content Sharing and Creation; SciStarter for Citizen Science and Research; and Google Workspace for Education for comprehensive educational solutions. Through an examination of these digital resources, this review aims to offer educators, researchers, and educational policymakers a comprehensive insight into how technology can enhance the integration of SSI into education, having the potential to promotes critical thinking, informed citizenship, and deeper engagement with real-world challenges.

Learning management systems (LMS)

Modular Object-Oriented Dynamic Learning Environment (Moodle): Moodle, a versatile Learning Management System (LMS), serves as an effective platform for the seamless integration of SSI into education. This robust tool offers a centralized repository for class materials, enabling educators to share a wide range of resources such as articles, videos, research papers, and other pertinent materials related to SSI within the group's dedicated library. It encourages students not only to explore these resources but also engage in thoughtful discussions surrounding them (Devi & Aparna, 2020).

Moreover, a professor has the capability to generate a brief survey to assess students' comprehension, aiding in making informed choices regarding specific course-related matters (Kc, 2017). Moodle can be used to gauge students' opinions and perspectives on specific socioscientific topics. These polls serve as catalysts for discussions, allowing students to comprehend the diverse array of viewpoints that complex issues often entail (Olugbade et al., 2023). To delve even deeper, Moodle discussion forums can be harnessed for profound conversations on SSI. Educators can pose open-ended questions, present ethical dilemmas, or introduce real-world scenarios associated with SSI, fostering an environment where students feel empowered to express their viewpoints, critically analyze information, and participate in respectful debates (Okada, 2008).

Lastly, the feedback feature within Moodle empowers educators to provide constructive input to students regarding their contributions to SSI discussions, assignments, and projects. This iterative feedback loop encourages students to refine their arguments and broaden their comprehension based on the received guidance (Xu, 2010), further enhancing their engagement with SSI in a meaningful and educational manner.

Google Classroom: Google Classroom, originally designed for class management and assignment distribution, can be a powerful tool for integrating SSI into education. To achieve this, a dedicated SSI class can be created to provide a central hub for organizing materials and discussions (Habiby, 2021). Relevant resources can be shared, SSI-related tasks can be assigned, and discussions can be sparked through the 'Classwork' sections. Open-ended questions, ethical dilemmas, or real-world scenarios can also be posed to encourage thoughtful conversations among students. Additionally, incorporating individual or group blogs and journals within Google Classroom. allows students to reflect on their evolving thoughts, ethical considerations, and personal growth as they engage with SSI over time.

Microsoft Teams: Microsoft Teams offers an enriched learning experience with its integrated features, real-time communication, and collaboration tools, setting the stage to foster the development of critical thinking, ethical reasoning, and in-depth exploration of intricate real-world challenges. By harnessing Microsoft Teams' file-sharing capabilities, users can seamlessly upload and share a diverse array of resources about SSI (Amilyana et al., 2021). This comprehensive resource repository ensures effortless access for students. The platform's "Assignments" feature empowers educators to craft and disseminate SSI-based projects and assignments with ease. Educators can provide students with clear instructions, well-defined deadlines, and transparent assessment criteria.

Lastly, Microsoft Teams encourages active student engagement within dedicated SSI channels, facilitating dynamic SSI discussions. In this forum, educators can pose thought-provoking questions, present ethical dilemmas, or introduce real-world scenarios linked to SSI (Esmeijer, 2021). This interactive platform enables students to participate in live discussions, thereby enhancing their critical thinking and communication skills.

Interactive classroom tools

Flip: Flip's interactive video platform offers a dynamic avenue for students to delve into and deliberate upon SSI creatively and engagingly. To effectively promote SSI engagement, educators can craft tailored SSI discussion topics, prompting students to articulate their thoughts and viewpoints through video responses (Fackler & Sexton, 2020). Moreover, integrating real-world scenarios related to these issues encourages students to consider implications, ethical dilemmas, and potential solutions. Facilitating peer interactions by encouraging responses to fellow students' video contributions fosters a collaborative learning environment. Flip also allows for a multifaceted approach, where students can present their research findings on specific SSI topics through video presentations. Organizing structured debates on socioscientific topics encourages students to critically analyze, articulate, and defend their perspectives (Merritt et al., 2023). Furthermore, educators can seamlessly intertwine SSI discussions with various subjects, emphasizing cross-curricular connections.

Assessment and self-reflection are seamlessly integrated into the platform, enabling educators to evaluate students' work and provide constructive feedback. Encouraging students to share their video discussions with a wider audience, perhaps even engaging in public discourse on SSI, extends the reach and impact of these vital conversations beyond the classroom. In summary, Flip empowers educators to create an enriched learning environment that cultivates critical thinking, ethical reasoning, and active engagement in the multifaceted realm of SSI.

PhET Interactive Simulations: PhET Interactive Simulations offers free, research-based science and mathematics simulations (PhET, 2023). These simulations provide students with the opportunity to explore complex scientific phenomena in a hands-on, digital environment (Perkins & Moore, 2012).These simulations can immerse students in real-world problem-solving scenarios, allowing them to experiment with variables and observe outcomes, thus gaining a deeper understanding of SSI topics (Geelan & Fan, 2014).

Interactive simulations, which are both engaging and research-based, provide a hands-on, digital platform for students to delve into complex scientific phenomena. While they serve as versatile tools across various science and math topics, their utility extends to addressing SSI as well. Educators can seamlessly integrate PhET simulations into lessons, making abstract concepts more accessible. By encouraging students to actively explore these simulations, instructors foster inquiry-based learning, prompting questions, hypotheses, and experiments within the virtual environment (Chang et al., 2016). This approach not only nurtures critical thinking and problem-solving skills but also enables students to engage deeply with SSI topics in an informal environment (Teig & Scherer, 2016). After student interactions with the simulations, class discussions provide a platform for debriefing experiences and promoting collaborative learning through group exploration. Thus, PhET interactive simulations prove invaluable for both traditional scientific concepts and their application to SSI, facilitating a holistic and immersive educational experience.

Nearpod: Nearpod emerges as a potent instrument for educators seeking to seamlessly incorporate SSI into their teaching methodologies. This versatile platform empowers the creation of interactive Nearpod lessons, meticulously designed to introduce chosen real world problems (i.e SSI topics) replete with background information, multimedia resources, and thought-provoking inquiries (Brown et al., 2021). With Nearpod's array of engagement tools, students are actively immersed in the learning process. Leveraging Nearpod's real-time feedback and formative assessment tools, educators gain valuable insights into student comprehension. This data-driven approach enables instructors to adapt their teaching methods dynamically to cater to the evolving needs of their students (Moorhouse et al., 2021).

Moreover, Nearpod facilitates the hosting of debates and discussions through its collaboration features. This setting empowers students to articulate their viewpoints and engage in constructive dialogues, fostering a rich exchange of ideas. The culmination of a Nearpod-driven lesson is marked by reflection and analysis, encouraging students to contemplate how their perspectives on the SSI topic may have evolved (Kinskey, 2020). Subsequently, educators can assign follow-up homework or research tasks related to the SSI topic, eliciting feedback from students. This iterative process serves to refine SSI integration efforts for subsequent lessons. The adaptability of Nearpod further shines as it accommodates both in-class and remote learning activities, rendering it a versatile platform for cultivating meaningful discussions and facilitating decision-making processes concerning real-world socioscientific challenges (Veng, 2023).

Pear Deck: Pear Deck, seamlessly integrated with Google Slides, emerges as a powerful ally for educators seeking to create dynamic, engaging presentations. Its core objective is to elevate student participation, transforming passive observers into active contributors to the learning process (Delgado-Algarra, 2020). Through the integration of interactive elements like polls, quizzes, and discussions, educators can not only assess student understanding in real time but also nurture peer interactions, fostering a collaborative and engaging classroom environment (Anggoro, 2021).

Moreover, Pear Deck catalyzes integrating real-world scenarios into presentations, illustrating the practical implications of SSI and promoting critical thinking. It encourages student reflection on evolving perspectives regarding the SSI topic and facilitates discussions, enabling peer feedback and collaborative learning. Beyond the presentation, Pear Deck extends its interactive components to enrich follow-up activities, such as research projects, thereby enhancing the overall learning experience (Deck, 2020).

Kahoot: Kahoot!, a game-based learning platform (Wang, 2015)., offers diverse opportunities to integrate SSI into education Educators can engage students by creating SSI-themed Kahoot! quizzes that challenge their understanding of complex issues, ethical dilemmas, and potential solutions. These quizzes serve as valuable tools for debate preparation, ethical dilemma discussions, and scenario analysis, fostering critical thinking and informed decision-making (Graham et al., 2020). Kahoot! also enables interactive classroom polls, historical perspectives exploration, and case study analysis, making SSI topics relevant and engaging. Moreover, educators can use Kahoot! to assess research findings, encourage current events analysis, and assess student knowledge on SSI topics, promoting active learning in a fun and interactive way.

Virtual meeting and communication tools

Zoom: Researchers can effectively employ Zoom and X (Twitter) as virtual meeting and communication tools to integrate SSI into education. Zoom provides a robust platform for hosting virtual SSI discussions, debates, and seminars, allowing researchers to connect with students, colleagues, and experts worldwide (Özbugutu, 2020). It facilitates real-time engagement, screen sharing for presentations, breakout rooms for group discussions, and recording for later reference (Fackler & Sexton, 2020). Researchers can organize SSI-focused webinars or guest speaker sessions on Zoom to expose students to diverse perspectives and expert insights.

X (Twitter): On the other hand, X (Twitter), with its broad reach and real-time nature, can serve as a dynamic platform for ongoing SSI discourse. Researchers can create dedicated SSI-focused X (Twitter) accounts or use relevant hashtags to curate and share resources, news articles, ethical dilemmas, and research findings related to SSI (Öztürk et al., 2021). Engaging with the education community through tweets, retweets, and discussions fosters networking, collaboration, and the exchange of ideas (Shaw et al., 2019). Researchers can also encourage students to participate in X (Twitter) discussions, allowing them to explore current SSI topics, follow influential voices, and contribute to broader societal conversations.

By harnessing both Zoom and X (Twitter), researchers can effectively cultivate an immersive and participatory SSI learning environment, promoting critical thinking and active engagement.

Assessment and feedback tools

Socrative: Socrative's versatile quiz creation features enable researchers to design quizzes tailored to specific SSI topics, fostering comprehension and critical thinking. By posing thought-provoking questions and ethical dilemmas related to SSI within these quizzes, researchers can gauge students' understanding and ethical reasoning in real time. Moreover, Socrative's real-time response gathering empowers researchers to adapt their teaching strategies based on immediate feedback (Wash, 2014). Researchers can identify areas where students may require further clarification or delve deeper into specific aspects of SSI. Additionally, Socrative's data analytics offer insights into individual and collective student performance, helping researchers tailor their instructional approach (Awedh et al., 2015).

Furthermore, Socrative can be employed for interactive discussions related to SSI by creating polls or open-ended questions that encourage students to share their perspectives and engage in dialogues. Researchers can then use the gathered responses as a basis for fostering deeper SSI discussions and

explorations. Incorporating Socrative into SSI-focused educational initiatives allows researchers to evaluate student comprehension, ethical reasoning, and opinions on complex real-world challenges systematically. It serves as an invaluable tool for promoting active learning and informed decision-making in the realm of SSI.

Content sharing and creation

YouTube: As a video-sharing platform, YouTube offers a wealth of educational opportunities for SSI integration. Researchers can curate or create videos that delve into various aspects of SSI topics, providing students with engaging visual content. These videos can include documentaries, expert interviews, or simulations illustrating real-world scenarios related to SSI (EducationMelbourne, 2020). YouTube's interactive features, such as comments and discussions, enable researchers to foster SSI-related dialogue and encourage students to share their thoughts, questions, and perspectives (D.K. Academy, 2021). By curating or producing high-quality SSI content on YouTube, researchers can provide students with accessible and engaging resources that promote critical thinking and informed discussions.

Miro: Miro is a versatile online whiteboard platform that researchers can employ to facilitate collaborative content creation and knowledge sharing in the context of SSI. Researchers can create virtual boards dedicated to SSI topics, where students can collectively brainstorm, visualize complex issues, and collaborate on projects (Benham et al., 2021). Miro's visual nature enables researchers to map out SSI concepts, ethical dilemmas, and potential solutions, fostering a deeper understanding of these issues. Furthermore, Miro's real-time collaboration features allow for synchronous group work, enabling students to collectively analyze data, create mind maps, and collaborate on research projects (Chan et al., 2023). By leveraging Miro, researchers can provide students with an interactive and visually engaging platform for content creation, enabling them to explore and synthesize SSI-related information collaboratively. Incorporating YouTube and Miro into SSI-focused educational endeavors enriches the learning experience by providing students with multimedia content and collaborative tools that promote active engagement, critical thinking, and a deeper understanding of complex SSI.

Citizen science and research

SciStarter: SciStarter, a digital platform to foster and study sustained engagement in citizen science (Hoffman et al., 2017), empowers students to actively participate in citizen science initiatives, where they can contribute to real scientific research projects related to SSI topics. Researchers can identify and curate citizen science projects on SciStarter that align with specific SSI topics. By engaging students in these projects, researchers encourage them to actively participate in real-world scientific endeavors while addressing complex socioscientific challenges (Brandt et al., 2022). Moreover, SciStarter's comprehensive database of citizen science projects and resources enables researchers to explore interdisciplinary connections between SSI topics and scientific investigations. This fosters a holistic understanding of the multifaceted nature of SSI.

Researchers can also employ SciStarter's tools to track and measure student engagement and contributions to citizen science projects, providing valuable insights into the effectiveness of SSI integration efforts. Additionally, SciStarter's community features facilitate discussions, knowledge sharing, and networking opportunities among educators, students, and citizen science practitioners (e.g., SciStarter, 2021). By incorporating SciStarter into SSI-focused educational initiatives, researchers can empower students to become active participants in authentic scientific research, enhancing their critical thinking, problem-solving skills, and ethical reasoning while contributing to meaningful societal change.

Comprehensive educational suites

Google Workspace for Education: Researchers can develop SSI-themed projects and assignments using Google Docs, Sheets, and Slides, encouraging collaborative research, data analysis,

and presentation creation. Google Drive provides a centralized repository for storing and sharing SSI-related resources, including articles, research papers, and multimedia content. Google Classroom serves as a centralized hub for educators to organize SSI lessons, assignments, and discussions. Researchers can create dedicated SSI classes within Google Classroom, facilitating seamless content delivery and student interaction. Utilizing Google Forms, researchers can design surveys and quizzes to assess student comprehension and gather feedback on SSI topics.

Google Meet offers a platform for hosting virtual SSI discussions, debates, and guest speaker sessions, connecting researchers, students, and experts in real-time. Google Sites enables researchers to build interactive SSI-themed websites or portfolios, providing students with a dynamic platform for showcasing their understanding and insights.

Moreover, researchers can encourage students to use Google Workspace's communication tools, such as Gmail and Google Chat, for collaborative SSI projects and to facilitate ongoing discussions. By integrating Google Workspace for Education into SSI-focused educational initiatives, researchers create a comprehensive and cohesive digital environment that fosters critical thinking, information sharing, and active engagement in complex SSI. Google Workspace for Education' has transformed the way students engage with SSI discussions by providing students with real-time collaboration features, allowing them to work together on SSI projects and discussions regardless of their physical locations. For example, students in different parts of the world can collaborate on a shared document, conduct research, and engage in discussions simultaneously. This real-time collaboration enhances peer-to-peer interaction and fosters a sense of global connectedness (Bond et al., 2021).

These platforms facilitate discourse and knowledge sharing among students, enabling collaborative research, peer review, and the co-creation of solutions to socioscientific dilemmas. Students can collaborate in real-time, regardless of their physical locations, fostering a sense of global connectivity and shared responsibility for addressing pressing societal issues (Sugino, 2021). This also helps to bring what might be place-based SSI contexts and initiatives into the local classroom (Newton et al., 2023).

In addition to the extensive range of educational tools mentioned, the integration of AI technologies is fundamentally transforming the educational landscape. Virtual Reality (VR) and Augmented Reality (AR) can serve as a dynamic catalyst in the creation of immersive, place-based learning experiences (Matovu et al., 2023). By harnessing augmented reality, educators can transport students to real-world locations and scenarios (Channa et al., 2021), enabling them to explore historical sites, cultural landmarks, or even environmental ecosystems (e.g., Newton et al, 2023). This not only enhances the engagement and relevance of the learning experience but also promotes critical thinking and problem-solving skills by allowing students to interact with and analyze these environments in a meaningful way (Pedro et al., 2019). AI-driven simulations offer a cost-effective and efficient means to study place-based phenomena, fostering a deeper understanding of real-world challenges. In this way, AI acts as a bridge between digital tools and real-world contexts, empowering educators, researchers, and policymakers to further advance the integration of SSI into education.

In summary, the integration of these digital tools into SSI education offers a holistic approach to fostering critical thinking, ethical reasoning, and active citizenship among students. Each tool contributes unique features and capabilities that collectively enhance the SSI learning experience, creating a rich and immersive educational environment. Researchers can tailor their use of these tools to align with their curriculum objectives, fostering a deeper understanding of SSI and empowering students to make informed decisions in a complex world.

THE IMPACT OF DIGITAL TOOLS ON STUDENT DECISION-MAKING, ARGUMENTATION SKILLS, AND ETHICAL REASONING IN THE CONTEXT OF SOCIOSCIENTIFIC DILEMMAS

The impact of digital tools on student decision-making, argumentation skills, and ethical reasoning in the context of socioscientific dilemmas is significant and multi-faceted. These tools offer a range of benefits that enhance students' abilities in the following areas:

Decision-Making

In the realm of SSI, digital tools play a pivotal role in enhancing students' decision-making abilities through three key avenues: increased access to information, exposure to real-world scenarios, and the provision of valuable feedback and assessment (Moura & Campagna, 2018). Firstly, these tools grant students unparalleled access to a diverse array of information pertinent to SSI topics. This unfettered access empowers them to gather a wide range of viewpoints, evidence, and data, laying the foundation for well-informed decision-making. Secondly, digital tools facilitate engagement with real-world scenarios through simulations, interactive discussions, and citizen science platforms like SciStarter (Solbu et al., 2023). This practical exposure enables students to delve into the complexities of SSI and comprehend the tangible consequences of their decisions. Finally, assessment tools such as Socrative and Kahoot offer students immediate feedback on their decision-making processes, allowing for reflection and adjustment (Licorish et al., 2018). This multifaceted approach, driven by digital tools, empowers students to make informed, thoughtful, and effective decisions in the face of socioscientific dilemmas.

Argumentation Skills

Digital tools have a profound impact on the development of students' argumentation skills, fostering engagement and collaboration, providing visual aids, and nurturing research and critical thinking abilities (Ravenscroft & McAlister, 2008). Firstly, interactive classroom tools such as Flip, Nearpod, and Pear Deck, along with virtual meetings on platforms like Zoom, create an environment where students are encouraged to articulate and defend their viewpoints collaboratively. This collaborative setting not only promotes the development of persuasive argumentation skills but also cultivates the ability to consider diverse perspectives (Benetos, 2023). Secondly, visual tools like Miro offer students visual aids to structure their arguments effectively (Radics, 2021). This includes creating mind maps, diagrams, and visual representations that enhance the clarity and persuasiveness of their reasoning. Lastly, digital tools facilitate research and critical thinking by offering resources for gathering evidence, evaluating sources, and strengthening argumentation through critical analysis. By incorporating these tools, students not only refine their ability to construct persuasive arguments but also become more adept at evaluating and synthesizing information, contributing to their overall skill development in the context of socioscientific dilemmas (Walker & Zeidler, 2007).

Ethical Reasoning

The central role of ethics in science education has been acknowledged by scholars as in integral part of classroom pedagogy and character development, particularly as it conceptualized within the SSI framework (Bazzul, 2016; McCory & Reiss, 2023; Sexena, 2019). Within the context of SSI, digital tools play a pivotal role in nurturing ethical reasoning among students through the presentation of ethical dilemmas, fostering community engagement, and providing immediate feedback. Firstly, these tools introduce students to ethical dilemmas related to SSI, challenging them to delve into the moral dimensions of their decisions. Through discussion platforms and simulations, students are prompted to consider the ethical implications of their choices, fostering a deeper understanding of the ethical complexities surrounding SSI (Pena-Silva et al., 2022). Secondly, virtual communication tools like X (Twitter) and collaborative online environments facilitate community engagement, enabling students to participate in discussions on ethics within a broader community. This exposure to diverse perspectives

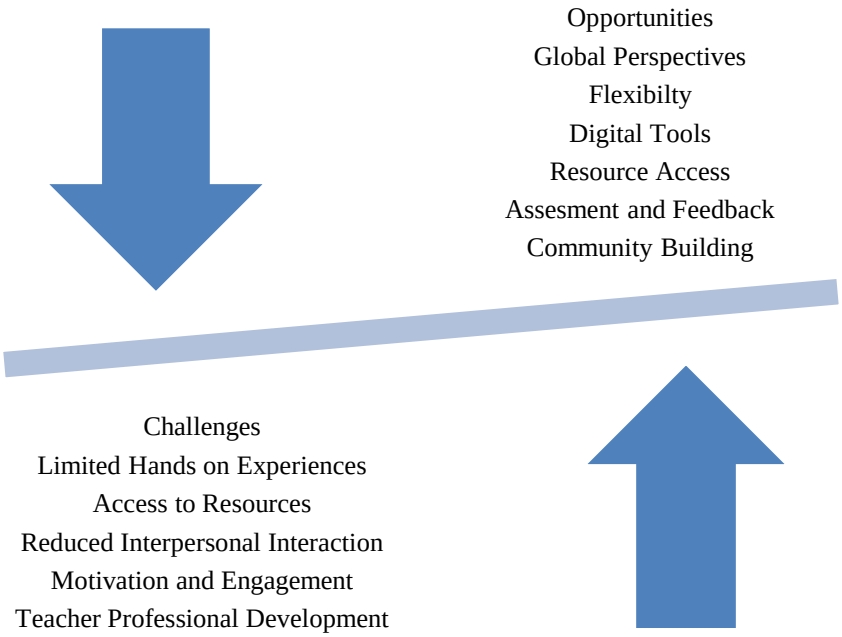
and ethical viewpoints encourages critical thinking and ethical reflection. Lastly, assessment tools such as Socrative incorporate questions that encourage students to reflect on the ethical implications of their decisions. This immediate feedback loop not only reinforces ethical reasoning but also instills a sense of responsibility and mindfulness in students as they navigate the intricate ethical landscapes of socioscientific dilemmas (Barbosa et al., 2021). In this way, digital tools become catalysts for the development of ethical reasoning skills within the SSI educational context.

However, it's important to note that the impact of digital tools on these skills depends on various factors, including the effectiveness of tool implementation, teacher guidance, and the willingness of students to engage actively. Effective integration of these tools into the curriculum, along with teacher support and guidance, plays a crucial role in maximizing their impact on student decision-making, argumentation skills, and ethical reasoning regarding socioscientific dilemmas.

THE CHALLENGES AND OPPORTUNITIES OF TEACHING SSI IN ONLINE AND BLENDED LEARNING ENVIRONMENTS

Teaching SSI in online and blended learning environments offers both challenges and opportunities, particularly in the context of the global shift toward remote education.

Figure 2.
Challenges and Opportunities Teaching Socioscientific Issues in Online and Blended Learning Environments



One of the foremost challenges is the limitation of hands-on experiences. In traditional settings, students benefit from practical laboratory work and interactive experiments, which play a pivotal role in comprehending the practical dimensions of SSI topics (Sadler, 2009). In online environments, replicating these hands-on experiences can be challenging (Kukulska-Hulme, 2012), potentially leading to a gap in the students' understanding of the real-world applications of SSI.

Another challenge arises from disparities in access to resources. Students' access to digital tools and resources may vary significantly, depending on their geographical location, socio-economic status, or institutional support (Li & Ranieri, 2013). This variance in access can impact their ability to engage effectively with SSI materials and digital tools, potentially creating inequalities in learning outcomes. Additionally, the shift to remote education can result in reduced interpersonal interaction. Face-to-face interactions in traditional classrooms foster peer collaboration, lively discussions, and debates on SSI

topics. In an online setting, these opportunities for rich interpersonal engagement may be limited, potentially hindering the development of students' critical thinking, argumentation skills, and ethical reasoning (Simamora, 2020).

Maintaining student motivation and engagement is another significant challenge in remote settings (Basar et al., 2021). Online learning can sometimes lead to feelings of isolation, making it essential for educators to employ innovative strategies and digital tools to sustain student interest in SSI discussions and ethical reasoning activities. Furthermore, educators themselves may face challenges related to professional development (Darazha et al., 2021). To effectively integrate digital tools and SSI topics into online instruction, educators may require additional training and support. This includes mastering the use of various educational technologies, adapting their teaching methods to online environments, and finding creative ways to foster deep engagement with SSI issues.

For instance, implementing ongoing professional development initiatives can equip educators with the requisite skills and knowledge to excel in the art of online teaching. Simultaneously, fostering supportive ecosystems through collaboration with educational institutions, administrative bodies, and ed-tech companies can nurture an environment conducive to educators' growth and effectiveness. Encouraging a sense of shared learning within the educational community, such as through the establishment of community of practice networks, can enable educators to share experiences, best practices, and insights, thereby collectively navigating the dynamic landscape of online education. In these ways, educators can be better prepared to meet the challenges posed by remote learning and elevate the quality of SSI education in digital environments.

Despite these challenges, online and blended learning environments present a myriad of opportunities (Grosseck, 2009) that can be used to effectively teach SSI. One of the most notable opportunities is the global perspective that online learning affords. Through digital connectivity, students can engage with SSI topics from a global standpoint, connecting with peers and experts worldwide. This global network allows them to gain diverse viewpoints, fostering a deeper understanding of the complexities surrounding SSI (Presley et al., 2013). Additionally, the flexibility inherent in blended and online formats is a significant advantage. These formats provide students with the freedom to explore SSI topics at their own pace, accommodating various learning styles and preferences. This flexibility can result in more personalized and effective learning experiences. Moreover, the wealth of digital tools and platforms available in online environments enriches the depth of SSI exploration. Virtual simulations, discussion forums, collaborative tools, and interactive multimedia resources offer dynamic and immersive learning experiences, facilitating a comprehensive understanding of SSI topics.

Online environments also provide unprecedented access to a treasure trove of digital resources (Wong, 2023). Students can easily access a vast array of articles, videos, expert discussions, and research materials related to SSI, augmenting their learning journey and broadening their knowledge horizons. Furthermore, digital assessment tools offer immediate feedback mechanisms (Chen et al., 2023). Educators can use these tools to gauge students' comprehension of SSI topics in real time and tailor their teaching strategies accordingly. This timely feedback loop enhances the effectiveness of the learning process.

Lastly, online platforms, including social media and discussion forums, serve as catalysts for community building and networking. Educators, students, and experts interested in SSI can come together in virtual spaces to share insights, exchange ideas, and collaborate on projects, creating a vibrant and supportive community that nurtures engagement and innovation in the field (Öztürk et al., 2021). In essence, the opportunities presented by online and blended learning environments significantly enhance the teaching and learning of SSI, fostering a dynamic and interconnected educational landscape. By recognizing these opportunities and addressing the challenges proactively, educators can create enriching and impactful learning experiences in the realm of SSI, even in remote education settings.

FUTURE RESEARCH DIRECTIONS

The globalization of SSI education opens doors for research on cross-cultural perspectives, shedding light on how diverse cultural backgrounds influence students' engagement with and comprehension of SSI topics. Complementing this, research in teacher professional development is poised to explore effective strategies for equipping educators with the knowledge and skills needed to proficiently employ SSI pedagogy and integrate digital tools into their teaching. Furthermore, as digital tools continue to play an integral role in SSI education, research may delve into ethical considerations surrounding AI use in assessment, data privacy concerns, and the development of strategies that foster a safe and inclusive online learning environment. These interconnected research directions collectively contribute to the ongoing evolution of SSI education, ensuring its relevance and effectiveness in the digital age while maintaining ethical and cross-cultural sensitivity.

In conclusion, this summary of opportunities and challenges serves as a compass guiding educators and researchers through the dynamic terrain of SSI education in the digital era. This comprehensive literature review highlights the symbiotic relationship between pedagogy and technology, showcasing how the integration of digital tools enriches students' SSI learning experiences. By investigating the impact on students' decision-making abilities, argumentation skills, and ethical reasoning, this review underscores the transformative potential of digital tools in shaping responsible and informed citizens of the 21st century. Moreover, it confronts the challenges and opportunities posed by online and blended learning environments, emphasizing the need for adaptable strategies in an ever-evolving educational landscape. As the world grapples with intricate socioscientific dilemmas, this review encourages educators to harness the power of technology and innovative pedagogical approaches, ultimately equipping students to navigate and contribute meaningfully to a complex and interconnected global society.

REFERENCES

Amilyana, A. S., & Noer, T. K. M. S., & Raharjo. (2021). A teaching material based on science, environment, technology, and society to improve student's critical thinking skills: Synchronous and asynchronous learning during Covid-19 pandemic. *International Journal of Recent Educational Research, 2*(4), 372-391. https://doi.org/10.46245/ijorer.v2i4.109

Anggoro, K. J. (2021). Pear deck. *RELC Journal, 52*(3), 645-647. https://doi.org/10.1177/0033688220936735

Awedh, M., Mueen, A., Zafar, B., & Manzoor, U. (2015). Using Socrative and Smartphones for the support of collaborative learning. https://doi.org/10.48550/arXiv.1501.01276

Barbosa, S. D. J., Barbosa, G. D. J., Souza, C. S. D., & Leitão, C. F. (2021, March). A semiotics-based epistemic tool to reason about ethical issues in digital technology design and development. In *Proceedings of the 2021 ACM Conference on Fairness, Accountability, and Transparency* (pp. 363-374). https://doi.org/10.1145/3442188.3445900

Basar, Z. M., Mansor, A. N., Jamaludin, K. A., & Alias, B. S. (2021). The effectiveness and challenges of online learning for secondary school students–A case study. *Asian Journal of University Education, 17*(3), 119-129. https://doi.org/10.24191/ajue.v17i3.14514

Bazzul, J. (2016). *Ethics and science education: How subjectivity matters*. Springer.

Benham, A., Callas, M., Fotherby, R., Jones, M., Chadha, J., Dobbin, M., & Johnson, A. W. (2021, October). Developing and Implementing an Aerospace Macroethics Lesson in a Required Sophomore Course. In *2021 IEEE Frontiers in Education Conference (FIE)* (pp. 1-9). IEEE. https:/doi.org/10.1109/FIE49875.2021.9637172

Benetos, K. (2023). *Digital Tools for Written Argumentation*. In *Digital Writing Technologies in Higher Education: Theory, Research, and Practice* (pp. 81-99). Springer International Publishing.

Bond, M., Bergdahl, N., Mendizabal-Espinosa, R., Kneale, D., Bolan, F., Hull, P., & Ramadani, F. (2021). Global emergency remote education in secondary schools during the COVID-19 pandemic: A systematic review. https://discovery.ucl.ac.uk/id/eprint/10136765/1/IPPO%20online%20learning%20-%20main%20report.pdf

Brandt, M., Groom, Q., Magro, A., Misevic, D., Narraway, C. L., Bruckermann, T., ... & Jenkins, T. (2022). Promoting scientific literacy in evolution through citizen science. *Proceedings of the Royal Society B, 289*(1980), 20221077. https://doi.org/10.1098/rspb.2022.1077

Brown, B., Pérez, G., Ribay, K., Boda, P. A., & Wilsey, M. (2021). Teaching culturally relevant science in virtual reality: "When a problem comes, you can solve it with science". *Journal of Science Teacher Education, 32*(1), 7-38. https://doi.org/10.1080/1046560X.2020.1778248

Chan, T. A. C. H., Ho, J. M. B., & Tom, M. (2023). Miro: Promoting collaboration through online whiteboard interaction. *RELC Journal*, Advance online publication. https://doi.org/10.1177/00336882231165061

Channa, F. R., Sarhandi, P. S. A., Bugti, F., & Pathan, H. (2021). Harnessing artificial intelligence in education for preparing learners for the 21st century. *Elementary Education Online, 20*(5), 3186-3186. https:/doi.org/10.17051/ilkonline.2021.05.346

Chang, H. Y., Hsu, Y. S., & Wu, H. K. (2016). A comparison study of augmented reality versus interactive simulation technology to support student learning of a socio-scientific issue. *Interactive Learning Environments, 24*(6), 1148-1161. https://doi.org/10.1080/10494820.2014.961486

Chen, C. M., Li, M. C., & Huang, Y. L. (2023). Developing an instant semantic analysis and feedback system to facilitate the learning performance of online discussion. *Interactive Learning Environments, 31*(3), 1402-1420. https://doi.org/10.1080/10494820.2020.1839505

Chowdhury, T. B. M., Holbrook, J., & Rannikmäe, M. (2020). Socioscientific issues within science education and their role in promoting the desired citizenry. *Science Education International, 31*(2), 203-208. https://doi.org/10.33828/sei.v31.i2.10

Darazha, I., Lyazzat, R., Ulzharkyn, A., Saira, Z., & Manat, Z. (2021, March). *Digital Competence of a Teacher in a Pandemic*. International Conference on Information and Education Technology (ICIET) Conference 2021. https:/doi.org/10.1109/ICIET51873.2021

Deck, P. (2020). *Pear Deck for Google Slides*. Peardeck Inc. Retrieved October 14, from https://www.wcupa.edu/education-socialWork/technologyCenter/documents/PearDeckQuickStart.pdf

Delgado-Algarra, E. J. (Ed.). (2020). *ICTs and innovation for didactics of social sciences*. IGI Global.

Devi, K. S., & Aparna, M. (2020). Moodle–An effective learning management system for 21st century learners. *Alochana Chakra Journal, 9*(6), 4474-4485.

D.K. Academy (2021, October 14). *Current Research Trends in Socioscientific Issues [video]* Youtube. https://www.youtube.com/watch?v=2MpCV8kWmZk

EducationMelbourne (2020, October 8). *Serendipity of Socioscientific Issues [video]* Youtube. https://www.youtube.com/watch?v=_iOf8iMQ3Jw

Elam, M., Solli, A., & Mäkitalo, Å. (2019). Socioscientific issues via controversy mapping: Bringing actor-network theory into the science classroom with digital technology. *Discourse: Studies in The Cultural Politics of Education, 40*(1), 61-77. https://doi.org/10.1080/01596306.2018.1549704

Esmeijer, L. M. (2021). *Future scenarios to introduce sustainability-related SocioScientific Issues in science education* (Unpublished master's thesis). Utrecht University.

Fackler, A. K., & Sexton, C. M. (2020). Science teacher education in the time of COVID-19. *The Electronic Journal for Research in Science & Mathematics Education, 24*(3), 5-13.

Graham, S. R., Tolar, A., & Hokayem, H. (2020). Teaching Preservice Teachers about COVID-19 through Distance Learning. *Electronic Journal for Research in Science & Mathematics Education, 24*(3), 29-37.

Geelan, D. R., & Fan, X. (2014). Teachers using interactive simulations to scaffold inquiry instruction in physical science education. In B. Eilam, & J. K. Gilbert, (Eds.), *Science Teachers' Use of Visual Representations* (pp. 249-270). https://doi.org/10.1007/978-3-319-06526-7_11

Gutierez, S. B. (2015). Integrating socio-scientific issues to enhance the bioethical decision-making skills of high school students. *International Education Studies, 8*(1), 142-151. http://dx.doi.org/10.5539/ies.v8n1p142

Grosseck, G. (2009). To use or not to use Web 2.0 in higher education? *Procedia Social and Behavioral Sciences, 1*, 478-482. https://doi.org/10.1016/j.sbspro.2009.01.087

Habiby, I. (2021, March). Improving students' NOS understanding through explicit-reflective learning with socio-scientific issues context. In *Journal of Physics: Conference Series* (Vol. 1806, No. 1, p. 012122). IOP Publishing. https://doi.org/10.1088/1742-6596/1806/1/012122

Hoffman, C., Cooper, C. B., Kennedy, E. B., Farooque, M., & Cavalier, D. (2017). Scistarter 2.0: A digital platform to foster and study sustained engagement in citizen science. In L. Ceccaroni, & J. Piera, (Eds.), *Analyzing the Role of citizen science in modern research* (pp. 50-61). IGI Global. https://doi.org/10.4018/978-1-5225-0962-2.ch003

Hwang, Y., Ko, Y., Shim, S. S., Ok, S. Y., & Lee, H. (2023). Promoting engineering students' social responsibility and willingness to act on socioscientific issues. *International Journal of STEM Education, 10*(1), 1-16. https://doi.org/10.1186/s40594-023-00402-1

Johnson, J., Macalalag, A. Z., & Dunphy, J. (2020). Incorporating socioscientific issues into a STEM education course: exploring teacher use of argumentation in SSI and plans for classroom implementation. *Disciplinary and Interdisciplinary Science Education Research, 2*, 1-12. https://doi.org/10.1186/s43031-020-00026-3

Karisan, D., & Zeidler, D. L. (2017). Contextualization of Nature of Science within the Socioscientific Issues Framework: A Review of Research. *International Journal of Education in Mathematics, Science and Technology, 5*(2), 139-152. https://doi.org/10.18404/ijemst.270186

Kc, D. (2017). Evaluation of Moodle features at Kajaani University of applied sciences–case study. *Procedia Computer Science, 116,* 121-128. https://doi.org/10.1016/j.procs.2017.10.021

Kukulska-Hulme, A. (2012). How should the higher education workforce adapt to advancements in technology for teaching and learning? *The Internet and Higher Education, 15*(4), 247-254. https://doi.org/10.1016/j.iheduc.2011.12.002

Kinskey, M. (2020). *Developing and facilitating socioscientific issues based science lessons: elementary preservice teachers' experiences.* (Unpublished doctoral dissertation). University of South Florida.

Licorish, S. A., Owen, H. E., Daniel, B., & George, J. L. (2018). Students' perception of Kahoot!'s influence on teaching and learning. *Research and Practice in Technology Enhanced Learning, 13*(1), 1-23. https://doi.org/10.1186/s41039-018-0078-8

Li, Y., & Ranieri, M. (2013). Educational and social correlates of the digital divide for rural and urban children: A study on primary school students in a provincial city of China. *Computers & Education, 60*(1), 197-209. https://doi.org/10.1016/j.compedu.2012.08.001

Matovu, H., Ungu, D. A. K., Won, M., Tsai, C. C., Treagust, D. F., Mocerino, M., & Tasker, R. (2023). Immersive virtual reality for science learning: Design, implementation, and evaluation. *Studies in Science Education*, 1-40. https://doi.org/10.1080/03057267.2022.2082680.

McCrory, A., & Reiss, M. (2023). *The place of ethics in science education: Implications for practice*. Bloomsbury Academic.

Merritt, E. G., Weinberg, A. E., & Archambault, L. (2023). Exploring energy through the lens of equity: Funds of knowledge conveyed through video-based discussion. *International Journal of Science and Mathematics Education*, 1-24. https://doi.org/10.1007/s10763-023-10352-3

Moorhouse, B. L., Lee, J., & Herd, S. (2021). Providing remote school-based professional support to teachers during school closures caused by the COVID-19 pandemic. *Learning: Research and Practice, 7*(1), 5-19. https://doi.org/10.1080/23735082.2020.1825777

Moura, A. C. M., & Campagna, M. (2018). Co-design: Digital tools for knowledge-building and decision-making in planning and design. *Disegnarecon, 11*(20), 1-3. https://doi.org/10.20365/disegnarecon.20.2018.ed

Newton, H.H., Annetta, L., & Bressler, D.M. (2023, April). *Using extended reality technologies within a socioscientific issues unit on climate change* [Paper presentation]. 94th Annual Meeting of NARST: A worldwide organization for improving science teaching and learning through research Conference 2023, Chicago, USA.

Okada, A. (2008). Scaffolding school pupils' scientific argumentation with evidence-based dialogue maps. *Knowledge cartography: Software tools and mapping techniques*, 131-162. https:/doi.org/10.1007/978-1-84800-149-7

Olugbade, D., Ojo, O. A., & Tolorunleke, A. E. (2023). Challenges and limitations of Moodle LMS in handling large-scale projects: West-African Universities lecturers' perspective. *Journal of Educational Technology and Instruction, 2*(2), 47-66. Retrieved from https://ijeti-edu.org/index.php/ijeti/article/view/71

Özbugutu, E. (2022). Opinions of Science Teachers Who Are Graduate Students on Teaching Socio Scientific Issues. *Bulletin of Education and Research, 44*(1), 1-21.

Öztürk, N., Bozkurt Altan, E., & Türkoğlu, A. Y. (2021). Discussing socio-scientific issues on X (Twitter): The quality of pre-service science teachers' arguments. *Journal of Education in Science Environment and Health, 7*(1), 72-85. https://doi.org/10.21891/jeseh.798167

Pedro, F., Subosa, M., Rivas, A., & Valverde, P. (2019). Artificial intelligence in education: Challenges and opportunities for sustainable development.

PhET Interactive simulations. (2023, October, 08). *PhET: Research and Development: How PhET simulations are designed, and the research process of refining the simulations to best promote learning.* https://phet.colorado.edu/en/research

Pena-Silva, R. A., Velasco-Castro, J. M., Zuluaga, L., Cocoma, G., & Jaramillo-Rincon, S. X. (2022). Fostering ethical reasoning in medical pharmacology through role-playing and digital tools. *The FASEB Journal, 36*. https://doi.org/10.1096/fasebj.2022.36.S1.R4797

Perkins, K., & Moore, E., (2012). PhET interactive simulations: Using implicit scaffolding to support productive inquiry learning. *Proceedings from EARLI SIG 20 Conference on Computer-Supported Inquiry Learning* (pp 24-25).

Presley L, Sickel A J, Muslu N, Johnson D, Witzig S, Izsi K, and Sadler T. A (2013). A framework for socio-scientific issues based education. *Science Educator, 22(1), 26-32.*

Radics, R. (2021, Novenber). *Methodological processing of gastronomic short stories using MIRO. COM platform.* 14th Annual International Conference of Education, Research and Innovation (ICERI) Online Conference, https://doi.org/10.21125/iceri.2021.2010

Ravenscroft, A., & McAlister, S. (2008). Investigating and promoting educational argumentation: Towards new digital practices. *International Journal of Research & Method in Education, 31(3*), 317-335. https://doi.org/10.1080/17437270802417192

Sadler, T. D. (2009). Situated learning in science education: Socio-scientific issues as contexts for practice. *Studies in Science Education, 45(1),* 1-42. *https://doi.org/10.1080/03057260802681839*

Sadler, T. D., Klosterman, M. L., & Topcu, M. S. (2011). Learning science content and socio-scientific reasoning through classroom explorations of global climate change. In T. D. Sadler (Ed.), *Socio-Scientific issues in the classroom: Teaching, learning, and research, (pp. 45–77).* Springer.

Simamora, R. M. (2020). The challenges of online learning during the COVID-19 pandemic: An essay analysis of performing arts education students. *Studies in Learning and Teaching, 1(2), 86-103.*

Sexena, A. (2019). *Ethics in science: Pedagogic issues and concerns*. Springer Nature.

Teig, N., & Scherer, R. (2016). Bringing formal and informal reasoning together—A new era of assessment? *Frontiers in Psychology, 7,* 1097. https://doi.org/10.3389/fpsyg.2016.01097

SciStarter. (2021, December 10). *MIT Climate CoLab*. https://scistarter.org/mit-climate-colab

Solbu, G., Heidenreich, S., Robison, R., & Ryghaug, M. (2023). Engagement methods for climate, energy, and mobility transitions.

Shaw, M., Walker, J., & Kafai, Y. (2019). Arguing about synthetic biology in 140 characters or less: Affordances of microblogging for high school students' discussions of socioscientific issues. In Lund, K., Niccolai, G. P., Lavoué, E., Hmelo-Silver, C., Gweon, G., & Baker, M. (Eds.), A Wide Lens: Combining Embodied, Enactive, Extended, and Embedded Learning in Collaborative Settings, 13th International Conference on Computer Supported Collaborative Learning (CSCL) 2019, Volume 1 (pp. 526-533). International Society of the Learning Sciences.

Sugino, C. (2021). Student perceptions of a synchronous online cooperative learning course in a Japanese women's university. *Education Sciences, 11*(5), 231. https://doi.org/10.3390/educsci11050231

Veng, S. (2023). Using an online student response system to promote student engagement in critical thinking classes. *International Journal of TESOL Studies, 5*(1), 69-86. https://doi.org/10.58304/ijts.20230106

Xu, Y. (2010). Examining the effects of digital feedback on student engagement and achievement. *Journal of Educational Computing Research, 43*(3), 275-291. https://doi.org/10.2190/EC.43.3.a

Walker, K. A. & Zeidler, D. L. (2007). Promoting discourse about socioscientific issues through scaffolded inquiry. *International Journal of Science Education, 29*(11), 1387-1410. https://doi.org/10.1080/09500690601068095

Wang, A.I. (2015). The wear-out effect of a game-based student response system. *Computers & Education, 82,* 217-227. https://doi.org/10.1016/j.compedu.2014.11.004

Wash, P. D. (2014). Taking advantage of mobile devices: Using Socrative in the classroom. *Journal of Teaching and Learning with Technology, 99-101*. https://doi.org/10.14434/jotlt.v3n1.5016

Wong, R. (2023). When no one can go to school: Does online learning meet students' basic learning needs? *Interactive Learning Environments, 31*(1), *434-450.* https://doi.org/10.1080/10494820.2020.1789672

Zeidler, D. L. (2003). *The role of moral reasoning on socioscientific issues and discourse in science education.* Kluwer Academic Press.

Zeidler, D. L., Sadler, T. D., Simmons, M. L., & Howes, E. V. (2005). Beyond STS: A research-based framework for socioscientific issues education. *Science Education, 89*(3), 357-377. https://doi.org/10.1002/sce.20048

Zeidler, D. L., Herman, B. C., & Sadler, T. D. (2019). New directions in socioscientific issues research. *Disciplinary and Interdisciplinary Science Education Research, 1*(11), 1-9. https://doi.org/10.1186/s43031-019-0008-7

Zeidler, D. L., & Kahn, S. (2014). It's debatable!: Using socioscientific issues to develop scientific literacy K-12. *NSTA press.*

Zeidler, D. L., & Sadler, T. D. (2023). Exploring and expanding the frontiers of socioscientific issues: Crossroads and future directions. In N. G. Lederman, D.L. Zeidler, & J.S. Lederman (Eds.), *Handbook of Research on Science Education, Volume III (pp. 899-929)*. Routledge.

TÜRKÇE GENİŞLETİLMİŞ ÖZET

21. yüzyıldaki gelişmeler toplumu her alanda etkilemektedir. Hızla dijitalleşen dünyada geleneksel eğitim öğretim yöntemleri yerini dijital öğretim araçlarına bırakmasa da bu araçların derslere entegre edilmesi kaçınılmaz olmuştur. 21. Yüzyıldaki bu hızlı gelişmelerin toplum hayatına olumlu ve olumsuz bir çok etkisi olduğu bilinmektedir. Örneğin Dijitalleşme ve teknolojik ilerleme, iş dünyasında verimliliği artırır, iletişimi kolaylaştırırken dijital eğitim araçları, öğrencilere farklı öğrenme yöntemleri sunarak öğrenmeyi daha etkili hale getirebilir ve bilgiye erişimi artırabilir. Öte yandan bilgiye erişimin kolaylaşmasıyla birlikte bilgi kirliliği ve yanlış bilgilere erişim artabilir. Teknolojiye bağımlılık artabilir dijitalleşmeyle birlikte kişisel bilgi gizliliği ve çevrimiçi güvenlik konuları daha büyük bir önem kazanabilir. Bu noktada bilim ve teknolojideki bu gelişmelerin toplum hayatına etkilerini inceleyen sosyobilimsel konuların (SBK) derslere entegre edilmesi, bu sayede öğrencilere bilimsel düşünceyi geliştirme, toplumsal meselelere eleştirel bir bakış açısı kazandırma ve etik değerlendirme becerileri kazandırma (Zeidler, 2003) olanağı sunulması oldukça önemlidir.

Sosyobilimsel konular bağlamında ele alınan derslerin, öğrencilerin karmaşık toplumsal sorunlarla başa çıkmalarına yardımcı olmakla kalmayıp, aynı zamanda bilimsel okuryazarlık ve sosyal bilimsel akıl yürütme becerilerini geliştirdiği (Chowdhury vd., 2020; Gutierez, 2015; Hwang vd., 2023; Johnson vd., 2020; Karisan ve Zeidler, 2017; Zeidler vd., 2005; Zeidler ve Kahn, 2014) bilinmektedir. Bilinen bu yanları düşünülerek, dijital çağın topluma sunduğu fayda ve zararları, dijital araçları kullanarak sosyobilimsel konular bağlamında tartışmak öğrencilere gerçek dünya sorunları üzerinde düşünme, eleştirel düşünme ve problem çözme, etik ve ahlaki gelişim, disiplinler arası öğrenmeyi teşvik etme ve vatandaşlık eğitimi gibi önemli becerileri kazandıracağı düşünülmektedir.

Sosyobilimsel konular üzerine hazırlanmış alanyazın incelendiğinde SBK'nin fen eğitimine entegrasyonu için birçok çalışmaya rastlanmaktadır (Zeidler ve Sadler, 2023). Ancak, dijital teknolojilerin gelişimi, SBK eğitimine yönelik yeni soruları gündeme getirmektedir. Dijital çağda, geleneksel SBK eğitim yaklaşımları yeniden şekillenmekte ve yeni eğilimler ve fırsatlar ortaya çıkmaktadır. Bu nedenle, "Dijital Çağda SBK Öğretimi: Ortaya Çıkan Eğilimler ve Keşfedilmemiş Sınırlar" başlıklı bu derleme büyük önem taşımaktadır. Teknolojinin eğitim süreçlerine ve topluma daha fazla entegre olduğu bir dönemde, bu dijital araçların ve platformların SBK eğitimini nasıl geliştirebileceği eleştirel bir şekilde incelenmelidir. Bu derleme, SBK eğitimini etkileyen en son gelişmeleri, yenilikçi pedagojik yaklaşımları ve teknolojik araçları ortaya çıkarmayı hedeflemektedir. İnceleme, SBK pedagojisinin ve dijital çağın kesişimini keşfederek eğitimciler, araştırmacılar ve politika yapıcıları için değerli bilgiler sunmaktadır. Ayrıca, dijital çağın getirdiği fırsatlar ve zorluklara uyum sağlama ve gelişme ihtiyacını da vurgular.

Derlemede SBK ve dijital çağ üzerine mevcut araştırma ve yayınları sistematik bir şekilde analiz ve sentez ederek bir literatür taraması yapılmıştır. Bu yöntemde yer alan adımlar şunlardır: araştırma kapsamının belirlenmesi, ilgili literatürün taranması ve seçilmesi, ilgili literatürün analizi ve sentezlenmesi, boşlukların ve eğilimlerin belirlenmesi ve eleştirel değerlendirme ve yorumlama. Öncelikle araştırma kapsamı belirlenmiştir. Araştırmamızın odak noktası dijital araçların SBK öğretiminde kullanımını incelemektir. Bu amaçla SBK pedagojisi, dijital teknolojiler ve bunların kesişimi ile ilgili bilgi toplamak için akademik veri tabanları, Google Akademik, Eric ve Web of Science arama motoru ve indeksleri taranmıştır. Uygun makale ve çalışmaları seçmek için belirli anahtar kelimeler ve kriterler kullanılmıştır. İlgili literatürü topladıktan sonra, bu kaynaklardan gelen bilgileri analiz ve sentez edilerek sosyobilimsel konuların dijital araçlar ile öğretilmesi sırasında karşılaşılabilecek zorluklar ve fırsatlar hakkında bilgi verilmiştir.

Dijital araçlar, öğrencilerin sosyobilimsel düşünmeyi geliştirme ve gerçek dünya sorunlarına katkıda bulunma becerilerini güçlendirmelerine yardımcı olur. Bu çalışmada ele alınan dijital araçlar 7 alt kategoride sunulmuştur. Her bir kategori için örnek teşkil edebilecek bir veya daha çok dijital araca yer verilmiştir.

Öğrenme Yönetim Sistemleri kategorisinde Moodle, Google Classroom ve Microsoft Teams; Etkileşimli Sınıf Araçları olarak Flip, PhET, Nearpod, Pear Deck ve Kahoot; Sanal Toplantılar ve İletişim için Zoom ve X (Twitter)); Değerlendirme için Socrative; İçerik Paylaşımı ve Oluşturma için YouTube ve Miro; Vatandaş Bilimi ve Araştırma için SciStarter ve kapsamlı eğitim çözümleri için Google Workspace for Education gibi belirli örnekleri vurgulayarak çeşitli eğitim araçlarının işlevlerini ve avantajları açıklanmıştır. Bu dijital kaynakların incelenmesi yoluyla bu derleme, eğitimcilere, araştırmacılara ve eğitim politikası yapıcılarına, eleştirel düşünmeyi, bilinçli vatandaşlığı ve gerçek dünyadaki zorluklarla daha derin bir etkileşimi teşvik etme potansiyeline sahip teknolojinin SBK'nin eğitime entegrasyonunu nasıl geliştirebileceğine dair kapsamlı bir fikir sunmayı amaçlamaktadır.

Dijital araçlar, sosyobilimsel konularda öğrencilerin karar verme, argümantasyon becerileri ve etik muhakemelerini etkileyen önemli faydalar sunar: Karar Verme: Dijital araçlar, geniş bilgi erişimi, gerçek dünya senaryoları ve anında geri bildirimle karar verme becerilerini artırır. Öğrenciler farklı bakış açılarına erişir, pratik senaryolarla çalışır ve etkili düşünme becerilerini geliştirirler. Argümantasyon Becerileri: Bu araçlar işbirlikçi tartışmayı teşvik eder, görsel yardımcılar sunar ve araştırma ile eleştirel düşünmeyi geliştirir. Öğrenciler bakış açılarını ifade eder, görsel temsillerle mantıklı düşünceyi artırır ve bilgiyi değerlendirme ile sentezleme yeteneklerini geliştirirler. Etik Muhakeme: Dijital araçlar etik sorunları ele alır, topluluk katılımını destekler ve anında geri bildirim sunar. Öğrenciler, ahlaki boyutları keşfeder, farklı etik perspektiflerle etkileşime girer ve etik düşünceyi geliştirirler.

Dijital araçların bu becerilere etkisini en üst düzeye çıkarmak için etkili uygulama, öğretmen rehberliği ve öğrenci katılımı önemlidir. Bu derleme, teknolojinin SBK eğitimine nasıl katkıda bulunabileceği konusunda eğitimciler, araştırmacılar kapsamlı bir bakış sunmayı amaçlamaktadır. Aynı zamanda, SBK eğitiminin küreselleşmesi ve farklı kültürel bağlamlardaki etkilerini ele alarak kültürler arası perspektifler sunar. Öğretmenlerin mesleki gelişimine yönelik araştırmalar, eğitimcileri SBK pedagojisini ustalaşmaları ve dijital araçları etkili bir şekilde öğretimlerine entegre etmeleri için gereken bilgi ve becerilerle donatmaya yönelik stratejileri inceler.

Çevrimiçi eğitimde karşılaşılan temel zorluklardan biri, sosyobilimsel konuların uygulamalı deneyimlerinin sınırlı olmasıdır. Geleneksel sınıflarda bulunan laboratuvar çalışmalarını ve etkileşimli deneyleri çevrimiçi olarak yeniden oluşturmak zor olabilir. Ayrıca, öğrencilerin dijital kaynaklara ve araçlara erişimindeki eşitsizlikler, coğrafi konumları, sosyo-ekonomik durumları veya kurumsal desteklerine bağlı olarak değişebilir. Bu erişim eşitsizliği, öğrencilerin SBK materyalleri ve dijital araçlarla etkileşimini etkileyebilir. Ayrıca, uzaktan eğitime geçiş, tipik olarak yüz yüze sınıf ortamlarında gelişen eleştirel düşünme, tartışma becerileri ve etik muhakeme gelişimini sınırlayabilir. Aynı zamanda, çevrimiçi öğrenme, öğrenciler arasında izolasyon hissi yaratabilir ve bu, öğrenci motivasyonunu ve katılımını sürdürmeyi zorlaştırır. Eğitimciler, SBK tartışmalarını ve etik muhakeme etkinliklerini sürdürmek için yenilikçi stratejiler ve dijital araçlar kullanmalıdır. Bununla birlikte, dijital araçların ve SBK konularının çevrimiçi eğitime entegre edilmesi, eğitimcilerin ek eğitim ve destek gereksinimleri ile karşılaşmalarına neden olabilir.

Çevrimiçi ve karma öğrenme ortamları, etkili SBK eğitimi için birçok fırsat sunmaktadır. Özellikle, çevrimiçi öğrenmenin sunduğu global perspektif, öğrencilere SBK konularına dünya çapından bir bakış açısı kazandırır. Dijital bağlantılar sayesinde öğrenciler, dünya genelindeki akranları ve uzmanlarla iletişim kurarak farklı bakış açıları kazanabilirler. Bu global ağ, SBK konularını daha iyi anlamak için farklı perspektifler sunar. Ayrıca, çevrimiçi ve karma formatların esnekliği, öğrencilere SBK konularını kendi hızlarında keşfetme özgürlüğü sunar. Dijital araçların bolca bulunduğu çevrimiçi ortamlar, SBK araştırmasının derinliğini artırarak öğrencilere dinamik ve etkileşimli öğrenme deneyimleri sunar. Çevrimiçi ortamlar ayrıca öğrencilere benzeri görülmemiş bir dijital kaynaklara erişim sağlar. Diğer bir avantaj, dijital değerlendirme araçlarının öğrencilerin SBK konularını anlama düzeyini ölçmelerine ve öğretim stratejilerini buna göre uyarlamalarına yardımcı olmasıdır. Son olarak, çevrimiçi platformlar, topluluk oluşturma ve ağ kurma için katalizör görevi görerek bu alandaki katılımı ve yeniliği besler. Özetle, çevrimiçi ve karma öğrenme ortamlarının sunduğu fırsatlar, SBK öğretimini zenginleştirir ve

eğitimcilere, zorlukları proaktif bir şekilde ele alarak, uzaktan eğitim ortamlarında bile etkili öğrenme deneyimleri yaratma imkânı sunar.

Sonuç olarak, dijital çağda SBK eğitiminin dinamik ve sürekli gelişen manzarasına ışık tutmayı amaçlayan bu çalışma dijital araçların ve teknolojinin SBK eğitimine katkılarına odaklanırken, eğitimcilerin, araştırmacıların dikkate alması gereken önemli faktörleri vurgular. Bu çalışma, öğrencileri karmaşık toplumsal sorunlara hazırlama ve onları etkili vatandaşlar olarak yetiştirme yolunda atılması gereken adımları ele almaktadır.