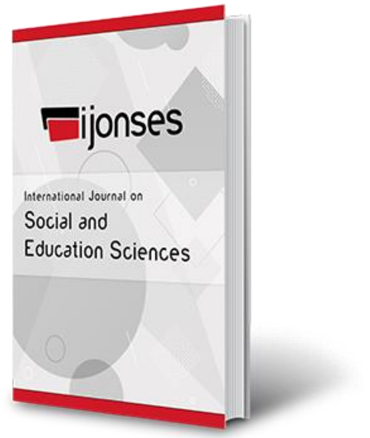

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Beyond the Acronym: Interconnections of STEAM, the Humanities, and Digital Citizenship

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Beyond the Acronym: Interconnections of STEAM, the Humanities, and Digital Citizenship

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Abstract

This study examines interdisciplinary and transdisciplinary interconnections within STEAM (Science, Technology, Engineering, Art, and Mathematics), the humanities, and their collective impacts on civilizations over time. This study includes a comprehensive overview of STEAM education and its integration with historical context and explores relationships beyond the acronym of STEAM itself, with an emphasis on STEAM advancements, the humanities, and digital citizenship for contemporary learners. The role of humanities in relation to STEAM is considered for delving into the historical background of robotics, the technological evolution from simple machines to complex tools for machine learning, engineering innovations during Industrial Revolutions, the Renaissance for creativity, and the Maker Movement for makerspaces in fostering innovation. The researchers consider how scientific, technological, engineering, and mathematical advancements have shaped societal development, as well as the historical roles of artistic expression on cultures. An analysis of interdisciplinary and transdisciplinary connections among STEAM disciplines within historical contexts creates a holistic educational view of societal evolution. The researchers also reflect on the contemporary implications of historical STEAM developments, advocating for the integration of historical context into STEAM curricula – and STEAM curricula into the humanities – for cultivating critical thinking, creative thinking, and a deeper understanding of civilization's interconnectedness.

Introduction

STEAM-Powered Histories: Connecting for Creativity

Interconnecting art into STEM (Science, Technology, Engineering, and Mathematics) education as STEAM cultivates critical thinking, innovation, and creativity and enriches learning experiences by fostering active engagement through a comprehensive skills approach (McGarry, 2018). Science, Technology, Engineering, Art, and Mathematics (STEAM) philosophy is an interdisciplinary construct that connects disparate disciplines for evaluating across a content area. Moreover, transdisciplinary approaches include not only connecting disparate disciplines, but also incorporating content from multiple perspectives between and within all disciplines for perspective beyond content foci. Transdisciplinary learning environments are innovative settings that foster integrative approaches between subject areas, encouraging cooperative and connected curriculum through gathering information from various sources to enhance critical thinking and dispositional practice (McGarry, 2018). When STEAM learning environments interconnect both interdisciplinary and transdisciplinary perspectives, they present innovative teaching and learning opportunities for all.

While an interdisciplinary and transdisciplinary STEAM construct interconnects content foci across and between the acronym of STEAM, providing students with prospects beyond the acronym and into other disciplines, such as the humanities, affords learners with opportunities to consider historical, cultural, and philosophical perspectives that enrich their understanding and application of scientific, technological, engineering, artistic, and mathematical concepts in real-world contexts. Blending and imparting understanding across, between, and beyond the acronym of STEAM for the humanities also provides opportunities to establish a Community of Practice (CoP) in learning spaces for student-led reflection and mentoring for communal knowledge sharing (Dignam, 2024).

Historically, and especially during the Renaissance, inquiry among learners and researchers occurred in communal settings in the form of guilds for supporting the interests and acquisition of knowledge for passing down to others. Guilds were institutions that imparted knowledge, skills, and dispositions in scientific, artistic, crafts, and trade professions for fostering a sense of community, mentorship, and tradition, ensuring the preservation and evolution of expertise across diverse disciplines (Li et al., 2023; Lucassen et al., 2008; McGarry, 2018). While contemporary learning tends to separate and compartmentalize disciplines, during the Renaissance, inquiry was embraced as interconnected disciplines, with artists learning, questioning, and reflecting alongside scientists through formal and informal dialogue and collaboration (Li et al., 2023; McGarry, 2018). A goal of this study is to promote contemporary guild learning in a digital era.

Although contemporary, siloed learning spaces no longer share traditional guild-like learning practices, interdisciplinary and transdisciplinary STEAM learning beyond the acronym for the inclusion of the humanities, presents opportunities for learners to communicate, reflect, self-assess and forge modern-day, guild-like environments (McGarry, 2018; Prak, 2003). This study argues for contemporary learning spaces to embrace guild philosophical constructs for creating a Community of Practice (CoP) in learning environments for modern-day learners to inquire and impart knowledge. Furthermore, utilizing a plethora of evolved contemporary digital media, such as web tools and online sharing platforms creates opportunities for forging a digital Community of Practice (dCoP) mindset in classrooms for establishing guild-like learning environments. Digital Communities of Practice (dCoPs) embrace technology for promoting students' social-emotional learning, growth for social capital, and collaboration for reflection among student learners (Dignam, 2024). This study aims to explore learning beyond the acronym of STEAM by interconnecting the humanities and creating guild-like dCoPs in classrooms for contemporary student inquiry and the construction of knowledge.

Interdisciplinary and Transdisciplinary Learning

Interdisciplinary and transdisciplinary teaching and learning are central to STEAM philosophy. Discussions on interdisciplinary learning benefits educators and systems by enhancing their recognition of distinctions among disciplines, leading to heightened awareness and comprehension for resolving disparities, as well as teacher leadership development and improved communication and collaboration in STEM education (Rabin et al., 2021). Conversations also create community among educators from diverse disciplines and perspectives, adding to the development of a dCoP (Dignam, 2024). While interdisciplinary conversations and communications are important for creating meaningful STEAM curricula for students, interconnected conversations also result in empathetic perspective-taking between educators with respect to how students often struggle to connect content from one discipline to another. Discussions and dialogue contribute to promoting students' social-emotional learning by nurturing empathy, respect, and comprehension for learners, thereby supporting students' social, emotional growth (Rabin et al., 2021).

STEAM for Academic Achievement and Social Capital

Facilitating positive emotional responses in students furthers an increase in social capital between both teachers and learners. Building social capital fosters student participation when interconnecting content, which enhances educational and career pathways for students (Saw, 2020). When teachers build social capital, they are better positioned to support student academic growth, emotional well-being, and foster communal trust and a supportive learning environment. STEAM fosters a sense of community and mutual support among students, which contributes to the development of strong social capital (Allina, 2018). Communal STEAM learning environments promote social capital and positively influence improved student academic performance, retention, and self-assurance by fostering social connections and emotional support for future academic and career aspirations (Puccia et al., 2021).

STEAM and Career Pathways beyond the Acronym

The future demands for STEM-related careers includes the need for educators to equip students with critical thinking skills and an understanding of the integration of science, technology, engineering, and mathematics for cultivating a proficient workforce capable of addressing complex real-world challenges (Hafni et al., 2020). For these reasons, it is critical for the establishment of a dCoP for educators to not only reflect and develop instructional skills, but to also engage in conversations for supporting interdisciplinary and transdisciplinary teaching and learning in a *guilded* environment that embraces the evolution of student work products. A dCoP capitalizes on the social, emotional skills development STEAM education affords for promoting creativity and cognitive, analytic skills in learners. Design thinking capitalizes on the thinking skills and practices designers use to create new ideas and solve problems through a flexible model that highlights clear process phases and practices, scaffolding between creativity and analysis, for facilitating innovation and creativity (Henriksen, 2017). Design processes support STEAM by helping teachers create more STEAM-based lessons with multiple artistic and scientific-related project facets that serve as a guiding structure for teachers' thinking and as part of students' STEAM and humanities experiences (Henriksen, 2017) (see Figure 1).

Given the meaningful cognitive and social, emotional learning STEAM provides for learners, creating conditions through the establishment of a dCoP with a guild mindset facilitates skills attainment for educators to better support students. In addition, there is a growing demand for professionals in various STEAM fields, including computer science, engineering, healthcare, and technology, which makes STEAM education relevant for learners beyond the acronym (Jiang, 2021). STEAM post-secondary and post-college career pathways are forecast to continue growing into the future, and it is estimated that 75% of the fastest-growing occupations require STEM skills (Tytler, 2020). The future forecasts for STEM occupations indicate a growing demand for career pathways including technology, healthcare, and engineering (Feder, 2022). It is therefore critical that students are provided opportunities to connect STEAM skills beyond the acronym for practical, interconnected humanities-included real-word applications as guilds, and that teachers are afforded creative, meaningful opportunities to develop professional growth and erudite skills for STEAM and leadership in a dCoP.

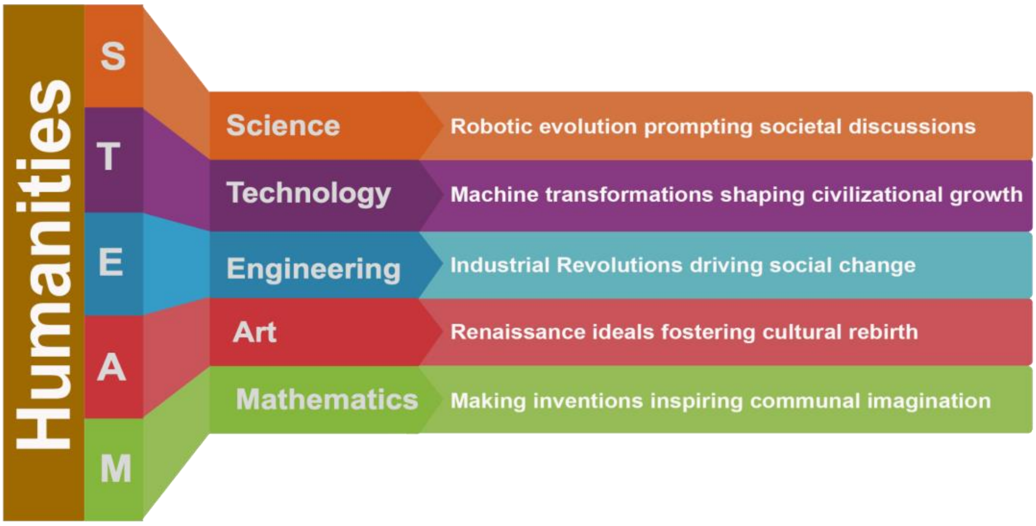

Figure 1. STEAM and the Humanities

Constructing Communities of Practice

Employing a constructivist digital Community of Practice (dCoP) philosophy provides a unique, highly malleable setting for affording students relevant, reflective learning pertaining to STEAM education. Relevant experiential, constructivist learning also supports in-person and digital social interactions for networking and knowledge sharing (Horan & Wells, 2005; Kolb et al., 1984; Riverin & Stacey, 2008; Vygotsky, 1978). Relevant, constructivist learning includes and employs the utilization of student-created works as artifacts for learners to examine as primary documents in the humanities for reflecting on knowledge shared and attained. When students create authentic artifacts representative of their knowledge, fellow students are empowered through knowledge sharing within the community of learners (Yarris et al., 2019).

Primary Artifacts and Experiential Learning

Artifacts enrich and enhance student learning experiences by stimulating critical thinking and helps instructors convey concepts in a more concrete and engaging manner (Hendrickson, 2016). In addition, digital artifacts assist teachers in creating a shared understanding of phenomenon studied, and enhance knowledge sharing by providing authentic visual literacies for supporting learning processes in constructing knowledge (McDonald et al., 2005).

Digital artifacts are student works and knowledge products pertaining to inquiry that students can share electronically as data, documents, images, art, etc. through webtools, online media, web software, website platforms, etc. Utilizing digital platforms for students to post work enables primary digital artifacts to develop and progress overtime through dCoP reflection and feedback, which makes digital artifacts living primary sources. Cai et al. (2023) asserts artifacts must be able to evolve over time and be shareable to support the further development and dissemination of knowledge. A dCoP provides a medium for hosting digital exemplars related to a variety of STEAM content for a natural evolution of knowledge for devising innovative, creative STEAM learning spaces and fostering reflective inquiry. The accumulation of knowledge gained through the use of digital exemplars allows teachers and researchers to extend theory for teaching within dCoPs for improved understanding of instructional practices, curricular development, and leadership development (Cai et al., 2023; Yarris et al., 2019).

Digital Citizenship beyond the Acronym

Digital citizenship encompasses the skills and knowledge required for individuals to successfully navigate the digital world. Digital citizenship equips students and teachers with essential skills so they can responsibly navigate the online world, including locating reliable information, content, and collaborating ethically and globally (Capuno et al., 2022). Developing digital skills for use in both dCoPs and life empowers learners to utilize digital tools for STEAM learning as a life skill and fosters ethical practices for responsible participation in digital industries and society. Digital citizenship is essential for both STEAM and humanities-based learning, as it supports digital inquiry-based exploration, collaborative problem-solving, and creative solution-finding across and between disciplines (Capuno et al., 2022; Öztürk, 2021; Prasetiyo et al., 2023).

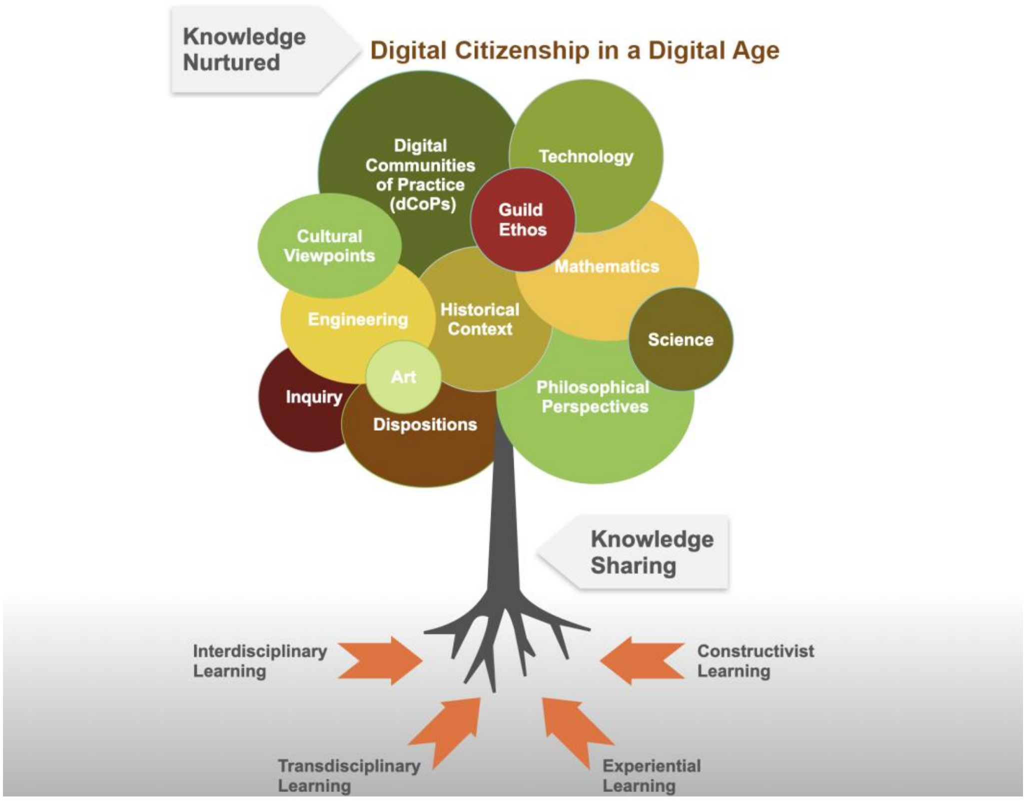

Figure 2. Interconnecting Concepts of STEAM, the Humanities, and Digital Citizenship

Providing explorations of STEAM and the humanities affords students with opportunities to develop a well-rounded understanding of the world from which we come and to which we aspire as digital citizens in a digital age (see Figure 2). This study and the sections that follow explore the role of the humanities in relation to each component word that comprise the acronym STEAM for interconnections and a comprehensive overview beyond the acronym, with an emphasis on STEAM advancements and digital citizenship for contemporary learners.

Artistry of *Science*: Exploring the Aesthetics of Robotics

Binary Beginnings and Historical Perspectives

Robotics is a long-evolved interdisciplinary field that is developing into a synthetic science focused on programming tasks, highlighting the significance of interdisciplinary cooperation and considerations regarding social impact (Koditschek, 2021). The inception of the term "robot" can be traced back to the playwright Karl Čapek, illustrating the initial phases of mechanization and automation and leading to the evolution of modern Artificial Intelligent (AI) robotics for advanced, self-derived decision-making (Kumar, 2014; Williams, 2019).

The evolution of robotics can be traced back to ancient civilizations' early automata and the tenth century's Carolingian Empire, during which tenant farmers were bound as serfs to landlords for laborious agricultural work, marking an era where the mechanization of tasks and labor began to lay the groundwork for future technological advancements in automated systems (Bloch, 2023; Trevelyan, 1999). Robotics has evolved from its origins in serfdom to practical applications in industries, modern AI advancements, and practical applications across industries, with ongoing research shaping its future trajectory. (Bloch, 2023; Scaradozzi et al., 2020; Trevelyan, 1999; Wolfram, 2019).

The interdisciplinary field of robotics holds promise for significantly impacting educational settings and learning processes through collaborative programming efforts focused on improving functionality, safety, and addressing the societal implications of robotic advancements (Koditschek, 2021; López-Belmonte et al., 2021). Artificial Intelligent (AI) robotics integrate Machine Learning (ML), and Deep Learning (DL) for enabling adaptable robots that are able to self-learn for decision-making. The essence of AI equips machines with human-like cognitive abilities such as decision-making and image recognition, while ML enhances tasks such as real-time navigation accuracy, and DL enables robots to autonomously execute diverse tasks intelligently, including image and speech recognition and object detection (Soori et al., 2023).

While the robots depicted in Čapek's play resulted in countless science fiction portrayals of robots as enslaved, mindless entities with the potential to rise up against their human creators, societal impressions of AI robots have also been influenced through these blurred interpretations. Isaac Asimov's science fiction narratives, notably his focus on robotic concepts and the establishment of the *Three Laws of Robotics*, has had an influential impact on the field of robotics (Stone, 2018). Contemporary AI robotics, though often associated with Asimov-related apocalyptic scenarios, actively perform practical tasks across diverse fields. Artificial Intelligent (AI) robotics hold the potential for fostering positive relations between humans and posthumans through the reinterpretation of altruism mediated by technology, thus overcoming conflictual *Frankenstein* interpretations (Odorčák &

Bakošová, 2021; Soori et al., 2023; Trevelyan, 1999).

Decoding Algorithms Byte by Byte

Cognitive Intelligence Algorithms (CIAs) function by replicating human cognitive processes, such as reasoning and decision-making, to improve machine abilities. Drawing inspiration from cognitive psychology, neuroscience, and social behavior studies, CIAs aim to create computational models of cognition for machines (Ren et al., 2023). View planning algorithms, another facet of robotics development, are designed to help robots capture detailed information in each view to accomplish goals such as reconstructing surfaces, identifying objects, inferring poses, and modeling 3D scenes. View planning algorithms influence active robot vision applications and enable robots to efficiently collect data for specific tasks (Zeng et al., 2020). Through CIA and view planning advancements, robotics continues to evolve, bridging the gap between human intelligence and machine capabilities. Communicating these evolutionary progressions byte by byte through the humanities provides interconnectedness of science and humanities for learners across disparate disciplines.

Attaining evolutionary self-awareness in robots that parallels human abilities, including spontaneous engagement with the environment, continuous learning, and intrinsic motivation, remains a major challenge in the field of robotics. Replicating human cognition in artificial systems poses challenges for robotics in terms of self-awareness and consciousness. Understanding the interconnections of the brain, body, and external environment, which is central for human self-awareness, is a key obstacle for AI and robotics (Mentzou & Ross, 2023). While self-awareness remains a major challenge in robotics, Human-Robotics Interaction (HRI) is a secondary area for researchers to develop conditions for robots to more easily, and emotionally, interconnect with and be readily embraced by society. Inner speech in robots can improve social skills and reliability by facilitating self-expression, fostering social connections, and enhancing transparency in HRI. Inner speech enables robotics to enhance human-like qualities, making robots more relatable and collaborative with humans (Chella et al., 2020; Wullenkord & Eyssel, 2020).

The integration of robots into society is dependent on HRI and human perceptions concerning AI robotics' intentions and safety. In reality, concerns regarding AI surpassing humans and becoming adversaries are dismissed due to the absence of intentions, emotions, and independent decision-making capabilities in AI systems, which preclude them from posing a danger to humanity. A lack of AI robotic self-awareness and consciousness in artificial intelligence systems has been emphasized by researchers (Li et al., 2021). Artificial Intelligence's inability to achieve self-consciousness has significant consequences, limiting the future of AI and interactions between humans and machines (Wang, 2023). As discussions concerning the ethics and safety of AI continue, addressing the limitations of AI in terms of self-awareness remains highly influential for shaping the future of robotics in society.

Cybernetics for Automating Society

Ethical, technological, and scientific uncertainties are key factors limiting wider implementation of industrial robots, including challenges related to HRI, object recognition, path planning, and optimization (Dzedzickis et al., 2021). Understanding human perceptions and attitudes towards robots is central in enhancing acceptance and effectiveness in HRI. Research by Dang & Liu (2023) identified that individuals with a growth mindset more effectively interacted with robots, expressed fewer negative feelings, and showed stronger support for robotics. Feelings of trust also influence the acceptance and effectiveness of robotic systems, shaping HRI dynamics. In studies performed by Kim (2022), an emphasis on the importance of trustworthiness in HRI included qualities such as ability, benevolence, and integrity as factors that impact trust levels. Insights from research on trust dynamics in HRI, such as the findings by Kim et al. (2020), provide valuable guidance for fostering successful human-robot engagement. Addressing uncertainties and cultivating trust paves the way for the development of more successful and efficient HRI, leading to broader acceptance and integration of robotics technologies into various aspects of society.

Understanding the dynamics of trust and acceptance in HRI is essential for the successful integration of robotics technologies into various aspects of society. Human trust in robots is significantly influenced by characteristics such as resemblance to humans, cognitive abilities, and emotional expression, emphasizing the importance of perceived similarity, intelligence levels, and emotional responsiveness in shaping trust during interactions (Kim, 2022). Additionally, aesthetic elements play a key role in evoking emotional responses and shaping the perceived trustworthiness of robots in human-robot interactions (Pinney et al., 2022). The informal exchange of social cues is equally important, involving nonverbal communication that occurs naturally during conversations and allows for the exchange of information through gestures, body language, and other nonverbal cues, facilitating understanding and building rapport between humans and robots (Breazeal et al., 2016). Considering key factors such as emotional perceptions and social cues, in addition to factors pertaining to ethics and regulation, better supports the integration of robotics technologies into society and fields, such as education and healthcare.

Of Circuits and Conscience

As robotics technology continues to evolve, robotic integration into various industries has resulted in significant societal impacts. Robot adoption has led to alterations in employment trends, wage structures, and has presented potential challenges linked to job displacement and income inequality within communities (Acemoglu & Restrepo, 2020). Industrial robots have been highly influential in shaping employment patterns, income distribution, and social cohesion. Robotics possesses the potential to diminish unity and solidarity within communities through changes in social inclusion, trust, and cooperation among members, which influences a communal sense of stability and togetherness (Jung & Lim, 2020). Although advancements in robot manipulation can positively transform society and industry by enhancing efficiency, safety, and convenience in everyday life, increased robot adoption in the workforce results in a reduction in routine manual job employment and contributes to a potential global reshaping of labor markets (De Vries et al., 2020; Oroy & Liu, 2024). The ethics and concerns regarding robotics integration are relevant areas of study beyond the acronym of STEAM and for the humanities.

In an effort to address societal concerns regarding the adoption of robots, it is important to consider human perception and psychological well-being during interactions between humans and robots to improve collaboration and alleviate tension (Zacharaki et al., 2020). Robots must exhibit social cues to establish successful relationships in society or civilization to improve user acceptance and address ethical considerations regarding responsibility and the impact of social presence on laws and regulations (Smakman et al., 2021). To further enhance HRI, Zacharaki et al. (2020) suggest that humans should provide demonstrations to model proper behavior for a robot to learn and subsequently improve its motions. A collaborative human-robotics approach not only fosters a sense of involvement and control but also enhances psychological safety during interactions. Moreover, interconnecting human demonstrations into humanities and robotic learning processes can lead to more natural and intuitive interactions surrounding the adoption of robotics technology.

As robotics technology continues to advance, societal, ethical dimensions of HRI are becoming increasingly important. Ethical aspects of HRI concern laws and regulations that include determining accountability, establishing ethical guidelines or penalties, and evaluating the influence of social robots on legal frameworks (Etemad-Sajadi et al., 2022; Smakman et al., 2021). Additionally, the moral autonomy of robots raises societal concerns about the ethical implications of machines making independent moral decisions. Moral autonomy raises questions concerning responsibility and accountability in cases where robots are involved in moral decision-making processes, especially in fields such as education and healthcare. Regulatory measures are necessary to address ethical issues in society and potential risks associated with robots gaining moral independence (Iphofen & Kritikos, 2021). It is essential to establish clear ethical guidelines and legal frameworks to ensure that robots operate within acceptable moral boundaries and to hold accountable parties responsible for any ethical breaches. Such measures are crucial for maintaining public trust and confidence in the ethical development and deployment of robotics technology and worthy of study across the humanities (see Table 1).

Table 1. Interconnecting Science of Robotics and Humanities

Aspect	Robotics	Humanities and Education
Historical Evolution	Early automata, Carolingian Empire, mechanization	Origin of "robot," evolution from serfdom to advanced AI and ML, historical context of technological evolution
Literary and Theatrical	Science fiction portrayals	Influence on societal perceptions of robots, impact of robotics acceptance, “Frankenstein” complex
Social and Ethical Implications	HRI, self-awareness, ethical guidelines, and regulations	Ethical concerns regarding autonomy, moral decision-making, social presence, digital citizenship in curricula
Technological Advancements and Societal Impact	CIAs, view planning algorithms, ML and DL	Bridging the gap between human intelligence and machine capabilities, digital literacy, social cohesion, community trust, and cooperation

While Karel Čapek’s 1921 play, *Rossum's Universal Robots,* and the laborious drudgery of agricultural farm work during the tenth century’s Carolingian Empire led to the inception of the colloquial term robot, the evolution of modern AI robots is mindful and possesses advanced self-automated decision-making. What began as endeavors in automated systems many centuries past, evolved into literary, theatrical, and science fictional works, and finally, contemporary works of hard science for the humanities. Historical, scientific advancements in automation are also interconnected to technological advancements in simple machines to complex robotic machina systems for ML, reflecting humanity's continual quest for efficiency and innovation throughout history. Within science education, digital literacy enables students to assess the validity of scientific information online, discern credible sources, and efficiently explore scientific materials (Prasetiyo et al., 2021). A digital citizenship framework enables students to reflect on robotics and AI ethics, conscientious usage, and making well-informed decisions for responsibly engaging with these technologies while comprehending their benefits and ethical implications.

Canvases of *Tech*: Painting the Story from Simple to Complex

Spinning the Gears of Innovation

The evolution of technology, from simple to complex machines, has shaped societies across the globe and influenced diverse disciplines throughout human history (Arthur, 2010). A pivotal figure in this technical progression was Archimedes of Syracuse, Sicily. Born in 287 BC, Archimedes made numerous contributions to fields spanning STEM and the humanities. Archimedes is credited with inventions such as the compound pulley, the catapult, and the Archimedes Screw, a hydrodynamic device used for lifting water that led the evolution from simple machines, to complex machines, and present-day STEM disciplines. Archimedes' innovations not only revolutionized their respective eras but continue to influence modern technological advancements that impact contemporary societies (Chondros, 2010). The Archimedes Screw, for instance, provided an ingenious auger-like mechanism within a pipe, facilitating the task of water transportation, a technology essential for human settlements and developing communities alike. Archimedes' inventions, tools, and machines inspired and informed countless luminaries across disciplines, from scientists and engineers to mathematicians and philosophers, leaving an indelible mark on the likes of Galileo Galilei and René Descartes.

Galileo Galilei drew inspiration from Archimedes' fundamental achievements in mathematics, mechanics, and engineering, which further influenced Galileo's scientific approaches and advancements in the field of physics. Similarly, René Descartes later made significant contributions to the fields of mathematics, philosophy, and physics, building upon the foundational work of pioneering figures such as Archimedes (Chondros, 2010). The development of simple machines, such as pulleys, levers, capstans, and screws, can be traced from ancient civilizations to the Renaissance, impacting contemporary societies and influencing technological advancements throughout history (Headrick, 2009; Seyhan, 2024). Archimedes' work on the mathematical theory of levers and compound pulleys, including his treatise on Plane Equilibriums, significantly advanced the understanding of pulleys and cranes in ancient times, despite some of his related works being lost (Seyhan, 2022; Seyhan, 2024). Vitruvius, a Roman architect and engineer known for his work on architecture and engineering principles, and Al-Jazari, a renowned engineer and inventor from the Islamic Golden Age celebrated for his *Book of Knowledge of Ingenious Mechanical Devices*, were also instrumental in shaping the evolution of simple machines and their applications (Ahmed et al., 2020; Seyhan, 2024).

Galileo Galilei's treatise on pulleys marked a pivotal milestone, being the first scholarly work to analyze machine theory through modern concepts, advancing the theoretical understanding of simple machines (Seyhan, 2022).

Galileo's groundbreaking effort laid the foundation for contemporary engineering principles across industries and bridged theory and application, catalyzing subsequent innovation that shapes modern societies (Currier, 2017). The evolution from simple to complex machinery significantly influenced advancements in engineering, construction, and transportation, where engineering innovations improved efficiency and safety standards (Arthur, 2010; Headrick, 2009).

Tech of Antiquity and Ingenuity

The origins of simple machines can also be traced back to ancient civilizations, where their applications and advancements laid the foundation for future technological progress (Chondros, 2010; Headrick, 2009). Ancient Egyptians, for instance, demonstrated remarkable ingenuity in utilizing pulleys for various tasks, such as extracting water from wells and potentially aiding in the construction of the pyramids. The discovery of the oldest known pulley, dating back to the 12th dynasty period, stands as a testament to the Egyptians' mastery in altering the direction of applied force (Ahmed et al., 2020; Chondros, 2010; Seyhan, 2024). Interconnections of technology, engineering, and machine-making can be traced as far back as Ancient Egypt, from approximately 1991 BC to 1802 BC, showcasing an early engagement with pulley systems and mechanical devices. An understanding of simple machines and their applications enabled ancient civilizations to undertake monumental acts of technology and construction, paving the way for further advancements in physics, mechanics, and mathematics (Currier, 2017; Seyhan, 2024).

Ancient Egyptians and Greeks engineered advanced hydro-technologies encompassing water lifting mechanisms, irrigation systems, and water purification techniques, showcasing enduring sustainability and continued relevance in contemporary applications (Ahmed et al., 2020). Ancient water technologies and inventions have roots dating back over 5000 years, originating during the Bronze Age around 3200-1350 BC, with civilizations such as the Egyptians and Minoans pioneering advancements (Ahmed et al., 2020; Chondros, 2010; Seyhan, 2022). Early hydro-technologies, including water lifting devices, irrigation systems, and water treatment methods developed by Egyptians and Greeks, persist in demonstrating sustainability and find ongoing application in modern technologies, such as water pumps, irrigation, and dams (Ahmed et al., 2020; Chondros, 2010).

While ancient Egyptian and Greek societies engineered a number of notable, technological machine advancements, several other cultures contributed to pioneering machine progressions as well as lessons learned with respect to the influence of society on technological innovation. The Roman Empire, for example, provides lessons learned regarding the stagnation of technological progress and implications for the humanities and STEM advancement. The Roman Empire was divided into the Western Roman Empire, lasting from 27 BC to AD 476, and the Eastern Roman Empire, known as the Byzantine Empire, which lasted until AD 1453.

While humanity experienced a number of technological inventions throughout these time periods, Roman technological advancement stagnated. In research conducted by Terpstra (2020) factors such as the Roman upper classes' disdain for non-agricultural activities, absence of state support for technology, and ruler indifference hindered Roman innovation, leading to limited progress compared to medieval Europe and Imperial China.

Europe's decentralized political environment from the 11th century onwards facilitated ongoing medieval technological advancements, while Imperial China, notably during the Tang (AD 618-907) and Song (AD 960-1279) dynasties, excelled technologically due to state support, fostering advancements in various fields including agriculture, iron industry, shipbuilding, and clockmaking, unlike the Roman Empire (Terpstra, 2020). Societal factors impacting technological progression are significant areas and considerations for modern day humanities and contemporary STEAM, as history demonstrates technological advancements are stimulated by competition and organized support, while indifference breeds inertia.

Wheels, Wires, and Code Streams

Simple machines, including the wheel and the inclined plane, aided in altering object motion and proved essential in early civilizations and construction endeavors (Currier, 2017; Headrick, 2009). Hero of Alexandria invented the aeolipile, a copper sphere filled with water that produced steam when heated, serving as an early turbine, while the Antikythera Mechanism from Ancient Greece (150-100 BC) is recognized as the earliest analogue computer, operated manually with gears to forecast astronomical events such as positions of celestial bodies and eclipses (Joshi, 2024). Simple machines formed the basis for modern technology and infrastructure, driving progress in transportation, agriculture, and construction, thereby boosting efficiency, productivity, and innovation across different sectors in civilizations (Chondros, 2010; Headrick, 2009; Currier, 2017).

The evolution of simple to more complex machines formed the basis for modern technology and infrastructure, driving progress in crucial sectors including transportation, agriculture, and construction. The advent of more complex object motion machines increased and fostered innovation across various facets of civilizations. From the earliest wheel to the most sophisticated machinery, the impact of machine technology has shaped the course of human progress and enabled feats of technological progress that have transformed societies over millennia. These technological, evolutionary machine progressions have led to the development of tech-based machines that artificially and virtually impact society in ways Archimedes and Ancient societies could not have imagined.

Mechanical Foundations to Neural Networks

Machine Learning (ML) is a contemporary technology that involves the development of machine algorithms that can learn from data to make predictions or decisions without explicit programming, bridging cybernetics/control and computer science. Cybernetics is the study of living and nonliving entities, such as humans and computers and how they communicate, regulate, and adapt to feedback (Dignam, 2024). The origins of ML are rooted in cybernetics/control, emphasizing convergence rates, with Frank Rosenblatt's perceptron in the late 1950s forging the foundation for modern artificial neural networks (Fradkov, 2020).

Cybernetics/control convergence rates indicate how quickly and effectively learning algorithms reach a stable and accurate solution during the learning process. The evolution of ML and consequently Deep Learning (DL) was significantly influenced by advancements in deterministic and probabilistic approaches in Moscow and Leningrad, the emergence of deep learning technology led by Geoffrey Hinton in the 1980s, and the foundational role of mathematical concepts including separation theorems and convex optimization (Fradkov, 2020). The progression from simple machines, such as the Antikythera Mechanism, led to more sophisticated machines and finally complex machines capable of recognizing letters in ML and artificial neural networks in AI.

Chatbots are machine software applications created to mimic human conversation, employing Natural Language Processing (NLP) and sentiment analysis to interact in human language via text or speech, serving diverse areas, such as education, business, e-commerce, health, and entertainment to replicate human interactions (Adamopoulou & Moussiades, 2020). The first chatbot, Eliza, was created in 1966 and was crafted to mimic the role of a psychotherapist by responding to user inputs in the form of questions. The current state of chatbot technology can also be used to aid students in virtual learning by assisting with educational content and responding to inquiries, leading to personalized learning, reduced language anxiety, and effective scalability for a larger student base (Adamopoulou & Moussiades, 2020). The continued evolution of chatbots have included advancements in AI usage that have revolutionized societal cybernetic communications for ML, DL, and virtual reality learning (see Table 2).

Table 2. Interconnecting Technology of Machines and Humanities

Era	Technology	Humanities and Education
Ancient Civilizations	Simple Machines	Water transport, engineering, and mechanics for an understanding of foundational engineering concepts and historical impact on society
Renaissance	Compound Machines	Advancements in physics and philosophy influenced by Archimedes' work. Integrating STEM principles with philosophical inquiry and scientific methods
Industrial Revolution	Complex Machinery	Innovations in machinery transformed industries and economies. Studying the intersection of technology, economics, and societal change during the Industrial Revolution
Contemporary	Machine Learning	AI, ML, Natural Language Processing (NLP), Chatbots, algorithms, digital literacy, HCI and cybernetic communications, ethical and social implications in daily life and professional environments

Technological advancements have significantly influenced societies for millennia, evolving from simple machines to complex machinery, and finally, ML for AI. The transition from basic tools such as levers and pulleys to the complex algorithms of AI has reshaped social structures, cultural norms, global industries, and a need for students to interconnect digital citizenship for responsibly utilizing technology (Fradkov, 2020; Öztürk, 2021; Prasetiyo et al., 2021). Technological machine advancements and engineering principles coevolved during the Industrial Revolutions, driving a simultaneous transformation in technological progress and societal changes (Currier, 2017). Each Industrial Revolution marked a pivotal point where the interconnection of technological innovations, engineering methods, and societal shifts considerably altered the human experience towards increased innovation and development.

Brushstrokes of *Engineering*: Forging Industrial Revolutions

From STEAM to Silicon

The evolutionary rise of industry fundamentally transformed societies by shifting from manual labor to mechanized production, revolutionizing industries, fostering economic growth, and instigating social changes. Progressive social change paved the way for modern industrialized societies, encompassing the emergence of a larger middle class and enhanced living standards for numerous individuals (Mohajan, 2019). Originating in England around 1750–1760, the First Industrial Revolution marked a transformative shift from human and animal labor to machinery, spurring economic growth, technological advancements, and social changes, particularly in the textile, iron, and steel industries (Groumpos, 2021; Mohajan, 2019). Engineering has been central in advancing the Industrial Revolutions through innovation, technology creation, and process improvement, resulting in enhanced efficiency, productivity, and quality across various industrial sectors throughout history (Mohajan, 2019; Sharma & Singh, 2020). The role of engineering has also been pivotal in shaping industries' evolution and facilitating the transition between industrial revolutions by consistently enhancing technology and making improvements for the betterment of humanity.

Engineering Designs in the Age of Industry

The First Industrial Revolution transitioned from manual labor to mechanized production processes and introduced steam power and mechanized factory systems, fundamentally altering manufacturing practices (Groumpos, 2021). Key machines and technologies of the First Industrial Revolution, such as the steam engine, spinning jenny, water frame, spinning mule, power looms, and steam-powered locomotives, revolutionized the textile and transportation industries by significantly enhancing efficiency and production capabilities. Machines and technologies ushered in the era of water power and steam engines, signifying the shift from manual labor to mechanized manufacturing processes (Sharma & Singh, 2020). As a result, society was transformed through the introduction of advanced technologies and complex machinery that revolutionized industries, leading to significant social changes such as the rise of factories, merchants, and bankers, the emergence of a larger middle class, and improvements in living standards for some. The societal impact of the First Industrial Revolution included the elevation of income levels, the stimulation of population expansion, and the conversion of manufacturing methods from manual labor to mechanized production (Groumpos, 2021).

Industry 2.0, also known as the Second Industrial Revolution, emerged in the 19th century, introducing electrical energy and assembly lines, transforming manufacturing practices in diverse sectors (Sharma & Singh, 2020). Advancements such as electricity and the implementation of assembly line production, introduced revolutionary innovations such as locomotives, steamboats, and hot blast iron smelting, transforming manufacturing methods and transportation systems. The societal impact of the Second Industrial Revolution transformed manufacturing methods with advancements such as assembly line production, locomotives, steamboats, and hot blast iron smelting, resulting in enhanced efficiency and productivity (Groumpos, 2021). Progress in transportation and manufacturing enabled urbanization, enhanced quality of life, and revolutionized societal interactions.

From Industrialization to Automation

In the mid-20th century, following World War II, the Third Industrial Revolution, or Industry 3.0, began with the implementation of partial automation through memory-programmable controls and computers, with production processes being executed without human intervention by robotics (Groumpos, 2021). The introduction of partial automation through memory-programmable controls and computers facilitated streamlined development processes without the need for human involvement (Sharma & Singh, 2020). Technological progress by means of computing facilitated automation that has dominated subsequent industrial evolutions. During this period of time, the Automation Revolution also took place, with engineering technologies transitioning from analog to digital automated production for globalizing supply chains. The integration of electronics and information technology, along with the globalization of supply chains, has benefited humanity by improving efficiency, boosting productivity, and expanding access to a broader array of products and services globally (Groumpos, 2021).

Industry 4.0, the Fourth Industrial Revolution, officially launched in the early 2010s, and merges cyber-physical systems, Internet of Things (IoT) connectivity, cloud computing, and cognitive technologies to transform manufacturing operations with smart factories and cutting-edge innovations (Sharma & Singh, 2020). The IoT is a network of interconnected devices equipped with sensors and software to collect and exchange data, enabling communication between devices and systems over the internet for remote monitoring, data analysis, and process automation (Pessôa & Becker, 2020). Advancements during this stage of societal and evolutionary STEAM are centered on digitalizing industries using information and communication technologies, with the introduction of intelligent machinery. Industry 4.0 is characterized by the transition from automation to autonomy in technology, allowing devices to autonomously make decisions using distributed information, progressing from basic and repetitive tasks to more intricate processes (Pessôa & Becker, 2020).

Industry 4.0 has also been defined by cutting-edge technologies such as IoT, big data analytics, and intelligent machinery to elevate manufacturing intelligence, leading to advanced smart production methods that are transforming manufacturing systems on a global scale (Groumpos, 2021). Interconnections between cyber-physical systems (CPSs) resulted in the emergence of IoT and smart products that possess autonomic self-properties, such as self-configuration, self-monitoring (Pessôa & Becker, 2020). The technological progress of Industry 4.0 positively impacts society by enhancing efficiency, productivity, and innovation within manufacturing operations, consequently fostering economic expansion and the generation of employment opportunities (Groumpos, 2021).

Human-Machine Dynamics and Industry

Industry 5.0 began to gain prominence and traction as a concept towards the end of the 2010s, emphasizing personalized manufacturing methods and design strategies (Groumpos, 2021). Industry 5.0 emphasizes sustainable development and collaboration between humans and machines, striving to improve manufacturing operations with intelligent facilities and cognitive computing systems, running concurrently with and expanding on progress made during Industry 4.0 (Sharma & Singh, 2020). Industry 5.0 highlights the partnership between humans and machines within industrial settings, aiming to blend human intellect with technology to boost productivity and foster creativity (George & George, 2020). The advent of Industry 5.0 is defined by its transitory emphasis from mass production to an era of tailored products through personalized manufacturing with a focus on flexibility and customization (George & George, 2020; Groumpos, 2021).

The evolution of automation, machines, and engineering has resulted in evolutions marked by both advancements in STEAM as well as societal civilizations and the need for students to develop applicable skills for digital citizenship (Capuno et al., 2022; Prasetiyo et al., 2021). Ancient civilizations and achievements gave rise to knowledge that enabled innovation for inventions throughout each Industrial Revolution, resulting in steam, electrical, digital, programmable, and finally automata (see Table 3). Industrialization and societal advancements beginning with the 18th century are interconnected to advancements that initially took place from the 14th through 17th centuries, the Renaissance. The 14th through 17th centuries marked a period of renewed interests in societal and cultural STEAM learning that was foundational for each Industrial Revolution, and is defined by the characterization of the arts for influencing discovery.

Table 3. Interconnecting Engineering of Industry and Humanities

Industrial Revolution	Technological Advancements	Humanities and Education
I 1.0	Steam engines, mechanized factory systems, steam-powered locomotives	Manual labor to mechanized production, initial social transformation of industry and society
I 2.0	Electrical energy, assembly lines, locomotives, hot blast iron smelting	Manufacturing and transportation, enhanced urbanization, quality of life, and labor dynamics
I 3.0	Partial analog to digital automation, memory-programmable controls, computing and robotics introduction	Digital revolution and society, more interconnected global economy, facilitation of globalized supply chains through digital automation
I 4.0 and I 5.0	Cyber-physical systems, IoT, cloud computing, personalized manufacturing, sustainable development	Emphasizing smart factories, technological autonomy, and human-machine collaboration. Implications of intelligent and autonomous systems

Watercolors of *Art*: A Renaissance of Historical Narratives

Strokes of Genius in Ink and Oil

The Renaissance took place from approximately 1400 to the early 1600s. The Renaissance was a new age of notable discovery that occurred during the 16th century. However, the Renaissance presents difficulties in defining its exact duration due to varying interpretations among historians (Wightman, 1964). The term Renaissance originated from a sudden literary style change in Italy, acknowledging a language fitting for human engagements with urban environments and nature and representing a rebirth or revival in the literary and artistic spheres during the era (Marusic & Broomhall, 2021; Wightman, 1964). In the Renaissance, artists and scientists engaged in visual exploration and experimentation as guilds, blurring the boundaries between art and science with an emphasis on the interconnectedness of natural laws (Li et al., 2023; McGarry, 2018; Wightman, 1964).

One of the most significant figures from the Renaissance was Leonardo da Vinci, who contributed to the era in terms of modern-day STEAM through anatomy and fluid mechanics, technological and engineering design, expressive artwork, and mathematics. Leonardo da Vinci was particularly innovative in terms of his anatomical studies, experiments and sketches related to fluid mechanics, water diversion, projectile stabilizers, cannon designs and forward-thinking approaches to engineering and technology (Marusic & Broomhall, 2021). Leonardo da Vinci's designs of simple and automated machines such as the drop propagation, mechanical clock, lever crane, mechanical drum, and self-supporting bridge exemplify a pioneering blend of classical mechanics with modern control systems, foreshadowing the technological advancements that fueled the Industrial Revolutions (Bucolo et al., 2020). Innovative designs and inventions inspired future generations to explore automation principles, contributing to the advancement of an artistic approach to engineering and technology in society. This artistic approach lends itself to today’s philosophical STEAM construct for education.

Figures such as Leonardo da Vinci, played a significant role in the development and implementation of scientific, technological, engineering, artistic, and 4mathematics endeavors that contributed to the cultural and political landscape of Europe during the Renaissance (Misa, 2022). Leonardo da Vinci's interdisciplinary and transdisciplinary approach, encompassing science, technology, engineering, art, and mathematics (STEAM), provided a foundation for modern STEAM philosophy and societal advancement, demonstrating the interconnectedness between these fields for fostering innovation and problem-solving skills. Leonardo da Vinci's ability to recognize and portray hidden patterns within chaotic natural phenomena, blending art and science through observations to fuel his creative process, demonstrates his deep understanding of structural intuition for interdisciplinary constructs (Deco et al., 2021). The innate ability to blend disparate disciplines for interdisciplinary and transdisciplinary expression, as exemplified by Leonardo da Vinci, emphasized the importance of the arts in fostering holistic understanding, empathy, and creative problem-solving for STEM to STEAM.

Narratives in Vivid Hues

During the Renaissance, the concept of humanism developed and was centered on the goodness of humanity with rational knowledge as a basis for addressing human problems. Renaissance humanists concentrated on disciplines such as grammar, rhetoric, history, poetry, and moral philosophy to understand and embody human values and conduct, while de-emphasizing mathematical subjects (Kallendorf, 1987). Humanism encompasses both individual actions and collaborative participation, emphasizing shared knowledge acquisition for communal learning and the development of identity within humanistic practices (Summit, 2012). Humanism redefined the humanities and shaped contemporary literature, rhetoric, and philosophy, prompting considerations regarding the social and material contexts of writing and emphasizing the intentionality of literature (Kallendorf, 1987).

Humanism and the Humanities emphasize the significance of acquiring knowledge for sustaining equilibrium among virtue, wisdom, leisure, and action, exemplifying diverse humanist behaviors and identities while prioritizing collaborative and interpersonal learning experiences for social learning (Summit, 2012). Humanism's influence on contemporary education seeks to prepare students for fulfilling, productive lives and to help them realize their fullest potential as individuals (Kallendorf, 1987). Humanism in contemporary education settings influences the cultivation of digital citizenship in students by emphasizing the importance of online ethical engagement, critical thought, and empathy for instilling an awareness of technology's societal implications for learners to navigate digital environments with regard for human values. As noted in research by Summit (2012), the acquisition of knowledge through communal, social actions aligns with contemporary STEAM philosophical approaches of Kolb’s experiential learning (1984) and Vygotsky’s theory of cognitive development (1978). The acquisition of knowledge through an interdisciplinary and transdisciplinary construct with a STEAM-humanities and humanistic mindset enables dCoPs to form and prepare 21st century students for navigating learning for digital citizenship.

Sketching the Past, Imagining the Future

The influence of Renaissance art on both modern art and STEM fields is evident in its contributions to realism, scientific understanding, perspective, and the mastery of light and shadow as both artistic techniques and scientific advancements (Chen, 2023). Artistic and modern-day STEAM influences were fostered by the guild structures of the era, which encouraged the blending of artistic and scientific knowledge, resulting in innovative approaches to both disciplines. Moreover, the Renaissance emphasis on humanism and the interconnectedness of knowledge were watercolors upon canvas for a holistic approach to education. The interconnectedness of humanism and knowledge is relevant for modern-day education, as it emphasizes the importance of humanity and digital citizenship in contemporary learners (Capuno et al., 2022; Öztürk, 2021; Prasetiyo et al., 2023) (see Table 4).

Table 4. Interconnecting art of Renaissance and humanities

Aspect	Renaissance Contributions	Humanities and Education
Historical Context	Renaissance “rebirth” in literary and artistic spheres	Understanding the influence of historical context on modern education and cultural development
Figures and Innovations	Leonardo da Vinci's interdisciplinary approach, Guild ethos	Highlighting the importance of interdisciplinary learning and STEAM education
Humanism and Humanities	Humanism, emphasis on human values, grammar, rhetoric, and moral philosophy	Humanistic values, communications, and collaborative learning in contemporary education
Artistic and STEAM Impact	Realism, scientific understanding, and the mastery of light and shadow	Interconnectedness of art and science, holistic educational approaches, and digital citizenship

Renaissance art's impact is further observed in the evolution of realism and the incorporation of humanistic values into artistic representations, interconnecting the blending of mathematics for creative expression (Chen, 2023; McMenamin, 2022). The reciprocity between art, science, and humanism also provides interconnections for exploring the palette of relationships between mathematics and makerspaces in contemporary contexts, where interdisciplinary and transdisciplinary collaboration through hands-on, experiential constructivism echoes the spirit of the Renaissance.

Palettes of *Mathematics*: Crafting Knowledge in Makerspace

Where Mathematics Meets Craftsmanship

Makerspaces are a fundamental element of STEAM education and enable students to participate in hands-on projects that merge science, technology, engineering, arts, and mathematics (Soomro et al., 2023). Engaging students in practical applications of STEAM and humanities concepts through hands-on learning enriches pedagogy by encouraging active participation, stimulating critical thinking, and enabling a more reflective comprehension of theoretical ideas through real-world practice (Budiyanto et al., 2020). Makerspaces promote knowledge-building through experiential learning and psychomotor outcomes by refining physical skills, and behavioral outcomes by influencing prosocial comportments (Mersand, 2021). The history of the maker movement dates back to the establishment of Make Magazine in 2005 by Dale Daugherty, who initiated Maker Faires to promote maker culture with gatherings that offered a venue for creators and innovators to exhibit their projects (Bull et al., 2022). The Maker Movement is a community-driven initiative that promotes collaboration, resource sharing, and peer-to-peer learning through makerspaces, serving as hubs for learners to engage in collective creative projects and build social networks (Niaros et al., 2017). The Maker Movement originated in the early 2000s, emphasizing the use of digital and physical fabrication tools to encourage a collaborative and innovative approach towards creative projects with Maker Faires beginning in 2006 and growing internationally, providing a platform for inventors, hobbyists, engineers, and educators to exhibit their work (Sung, 2018). Makerspaces promote diverse discussions, robust ideas, and interdisciplinary collaborations among students with different backgrounds and levels of expertise and supports STEAM education by enabling skill and knowledge development through creative solutions (Reynaga-Peña et al., 2020).

Making Meaning and Mindset Making

Makerspaces nurture students' creative mindset by encouraging self-expression and agency through hands-on projects, fostering creative, collaborative, project-based activities and interpersonal skills-building relevant to the humanistic needs of learners (Turakhia, 2023). The goals of makerspaces, emphasizing collaborative learning and skill development, align with Kolb’s experiential learning and Vygotsky's sociocultural theory, which emphasizes the significance of social interactions and guided learning in cognitive development (Bowler & Champagne, 2016). Enhancing STEAM transdisciplinary skills in conjunction with humanities disciplinary knowledge equips learners with the capacity to think critically, solve intricate problems, appreciate diverse viewpoints, and make ethical choices for digital citizenship and lifelong learning (Capuno et al., 2022; Prasetiyo et al., 2021; Taylor & Taylor, 2019).

In makerspace classrooms, constructivism is the cornerstone of learning and engages students in active, social exploration and discovery through hands-on experiences. Constructivism fosters collaboration among students for knowledge sharing and collectively working on projects, based on shared ideas through teamwork and communication, all of which are essential skills for success in diverse fields. A constructivist approach supports critical thinking by encouraging students to explore, question, and construct knowledge through practical, real-world projects, aligning with constructivist principles (Shah, 2019). Moreover, the integration of art and the mathematics of engineering in makerspaces transcends disciplinary boundaries, encouraging interdisciplinary collaboration and transdisciplinary learning. Interconnecting learning enables students to create projects that not only prioritize functionality but also emphasize aesthetic appeal, fostering creativity alongside technical proficiency (Park et al., 2018). Through these interdisciplinary and transdisciplinary approaches, makerspaces serve as dynamic environments where students develop a holistic understanding of concepts, skills, and their interconnectedness, preparing them for the complexities of the modern world.

DIY Tools for Making Magic

Aligning makerspace with mathematical, engineering education goals encourages students to persevere, experiment, and embrace a digital mindset of continuous effort for enriching students' competencies, understanding, and engagement with authentic constructing processes (Galaleldin et al., 2019). Digital physical tools such as 3D printers, CNC (computer numeric control) machines, and laser cutters enable students to create precise physical objects from digital designs, fostering creativity and hands-on learning (Martin, 2015).

Table 5. Interconnecting Mathematics of Makerspace and Humanities

Aspect	Makerspace Contributions	Humanities and Education
Historical Context	Maker Movement, Maker Faires, DIY collaboration, innovation, and inventing	Maker Movement and modern education for fostering a culture of creativity
Experiential Learning	Hands-on PBL, digital and physical tools 3D printers, CNCs, and laser cutters	Active participation, critical thinking, real-world application of concepts
Interdisciplinary Collaboration	Blending art and engineering, PBL, functionality and aesthetic appeal	Interdisciplinary learning, integration of STEAM with humanities, holistic learning
Humanistic Development	Fostering creativity, collaboration, PBL activities for building interpersonal skills	Social interactions, empathy, digital citizenship and lifelong learning

Creating learning opportunities that reach beyond the classroom to involve home and community settings can enhance students’ educational experiences (Becker & Jacobsen, 2020). Interconnecting interdisciplinary and transdisciplinary philosophies and the relevancy of *making* to the humanities into makerspaces involves creating environments that support transformative change through diverse learning processes (see Table 5).

Interconnecting diverse learning processes in makerspaces encourages interdisciplinary collaboration beyond the acronym of STEAM, fostering innovation and the creation of effective solutions to address complex societal challenges, ultimately leading to more holistic and impactful innovative and relevant lifelong learning (Barth et al., 2023).

Discussion

Autoethnography

The utilization of autoethnography provides authentic artifacts for detailing a variety of exemplars for creating a contemporary Community of Practice (CoP) for blending curricula beyond the acronym of STEAM in the humanities (Pinner, 2018). The contemporary environment established is a digital Community of Practice (dCoP) for utilizing digital artifacts in considering educational leadership, teaching, and learning. Employing digital autoethnography through portraiture methodology enables an immersive atmosphere that blends art and science through empirical aspects of inquiry with descriptive, aesthetic properties. A digital ethnographic approach enables the establishment of an environment for creating narratives through digital storytelling regarding phenomena by allowing researcher's voice with respect to the lived experiences of practitioners (Pinner, 2018; Vellanki & Prince, 2018).

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Digital Storytelling

Digital storytelling involves employing projects to share personal experiences, convey important values and lessons, and engage students in a powerful and impactful way (Skouge & Rao, 2009). The advent of digital technologies to support educational outcomes provides a variety of innovative and creative approaches for employing storytelling through technology for dCoPs to examine and reflect for envisioning knowledge-building and -sharing. In addition, employing autoethnography in presenting digital artifacts presents a digital environment for use at any time as a dCoP for experiential, reflective learning. In a study by Wu and Chen (2020), the researchers identified five orientations of educational digital storytelling as appropriative, agentive, reflective, reconstructive, and reflexive, each representing a distinct experience. Reflection is a central element in considering student performance and pathways of improvement. Reflective educational digital storytelling prompts students to self-contemplate their experiences, thoughts, and emotions, nurturing self-awareness, critical thinking, and personal development within an educational setting (Wu & Chen, 2020).

Of Pasts to Pixels: Sketching the Interconnectedness of STEAM

This study examined interconnections between disciplines encompassed by STEAM and the humanities, clarifying their cumulative influences on civilizations and humanity. By amalgamating a comprehensive review of STEAM education with historical narratives, the researchers illuminated nuanced relationships extending beyond the acronym of STEAM. Special emphasis was placed on the pivotal role of the humanities and the imperative of fostering digital citizenship to equip contemporary learners with essential skills. The symbiotic relationship between humanities and STEAM resulted in an exploration of historical precedents. From the scientific inception of robotics to the contemporary era of AI, from the dawn of simple machine technology to the impact of engineering and Industrial Revolutions, and from the artistic fervor of the Renaissance to the innovative spirit of the Maker Movement and mathematics, each epoch was scrutinized for its contributions to societal evolution. The researchers highlighted how advancements in STEAM have shaped the trajectory of human development, while also acknowledging the roles of interdisciplinary and transdisciplinary learning in concert with experiential learning and constructivism, linkages within historical settings provided a framework for holistic societal evolution. Furthermore, this study reflected on the contemporary significance of historical STEAM advancements and interconnections to humanities education. In essence, the findings emphasize the value of presenting blended, disparate curricula for a holistic understanding of human progress. Embracing a guild ethos and construct concerning the relationship between STEAM and the humanities imbues learners with the requisite skills and perspectives to navigate contemporary, lifelong learning.

Sculpting Reflections: Interconnections of STEAM, the Humanities, and Civilization

The study's findings illuminate the transformative potential of interdisciplinary and transdisciplinary approaches in education, particularly within STEAM and the humanities. Employing contextualized scientific and technological advancements within historical narratives enables educators to inspire a deeper understanding of their societal implications while interconnecting STEAM principles with humanities education, fostering critical thinking and a nuanced appreciation for the human experience. Digital citizenship education within STEAM and the humanities prepares learners for the challenges of the digital age and navigating the modern world. Moreover, by fostering collaboration between disparate disciplines, educators can create rich learning environments that encourage creativity, innovation, and critical inquiry, equipping learners to tackle the complexities of the 21st century with ingenuity and empathy.

Conclusion

Carved Closure: Interconnected Insights for Digital Citizenship

Interconnecting the dynamic relationship between STEAM and humanities illustrates their collective influence on civilizations throughout history. Interconnecting historical narratives into STEAM education and promoting digital citizenship are essential strategies for fostering a refined understanding of societal development among learners. Emphasizing collaboration between STEAM and humanities disciplines enables educators to cultivate critical thinking, creativity, and ethical awareness in students. In concert, interdisciplinary and transdisciplinary approaches afford promising methodologies for equipping learners with the skills and perspectives necessary to navigate the complexities of an ever-evolving contemporary world, thereby carving a more enlightened and empathetic future for humanity.

Stained Glass Images: Professional Erudition for Continual Growth

A requisite for establishing and employing learning environments that interconnect STEAM and the humanities is for teachers to be provided meaningful professional growth. The impetus for meaningful STEAM and humanities curricular development is for teachers to construct cognitively and socially relevant content for presenting to students for knowledge building. Teachers traditionally seek professional growth through professional development opportunities, which are general in focus and not specific to teachers' needs. Traditional approaches to professional development are often viewed as inadequate because they are passive and individualistic, failing to provide the necessary depth and ongoing support required for significant growth and transformation in teaching practices (Stewart, 2014). In addition, interconnecting STEAM and the humanities is a nontraditional approach to presenting disparate disciplines and requires supporting teachers so they can support learners.

Professional development also often occurs offsite, rather than onsite and constructed by external personnel and entities. As a result, professional development is commonly perceived as passive and individual, whereas professional learning is characterized by active collaboration and sustained support within a community of practice (Stewart, 2014). Professional learning is targeted and occurs onsite, which differs from professional development, as professional learning is periodic (ongoing and revisited) as compared to professional development, which is episodic and irregular. In research conducted by Dignam (2023), professional erudition encompasses both on-site professional development and professional learning and is targeted for providing continuous and revisited support for educators' professional growth needs. The term professional erudition signifies the qualities of targeted site-based professional development and professional learning, providing a continuous and reflective approach for professional growth (Dignam, 2024). Affording educators STEAM and humanities professional erudition provides teachers with meaningful, transferable curricula for promoting student academic, social, and emotional learning beyond the acronym.

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