ISSN: 2149-214X

Journal of Education in Science, Environment and Health

www.jeseh.net

Beyond the Acronym: Intersections of STEAM, Cybernetics, and Leadership Nurturing

Christopher Dignam
Governors State University

To cite this article:

Dignam, C. (2024). Beyond the acronym: Intersections of STEAM, cybernetics, and leadership nurturing. *Journal of Education in Science, Environment and Health (JESEH), 10*(2), 155-170. https://doi.org/ 10.55549/jeseh.700

JESEH
Journal of Education in Science, Environment and Health
Volume 10, Issue 2, 2024
https://doi.org/10.55549/jeseh.700

Beyond the Acronym: Intersections of STEAM, Cybernetics, and Leadership Nurturing

Christopher Dignam

Article Info

Article History

Published:
01 April 2024

Received:
21 January 2024

Accepted:
23 March 2024

Keywords

STEAM,
Cybernetics,
Constructivism,
Autoethnography,
Leadership nurturing

Abstract

The theoretical model presented in this study explores the transformational potential of a digital Community of Practice (dCoP) within higher education, focusing on Science, Technology, Engineering, Art, and Mathematics (STEAM) education. A dCoP serves as a virtual space for educators to exchange knowledge, foster interdisciplinary collaboration, and construct meaning through discourse. Through the use of digital artifacts, a dCoP provides tangible exemplars for intersecting abstract concepts to real-world applications, thus strengthening educational experiences and outcomes. This study emphasizes the cognitive, social, and emotional skills developed through STEAM education, projecting future career growth for learners in these areas. Establishing a dCoP for teachers in higher education facilitates the transfer of interdisciplinary and transdisciplinary skills to students, supporting STEAM learning and future career opportunities. Additionally, this study employs portraiture and autoethnography methodology for storytelling and cybernetic learning. The incorporation of a cybernetic mindset, presented through a theoretical Cybernetic Three-Realm Model, enriches a dCoP by addressing (1) a Canvas for Scholarship of Teaching and Learning (SoTL), (2) an Artist's Palette for Authentic Artifacts, and (3) The Paints of Modalities for Learning. This theoretical construct affords a tangible framework for fostering STEAM skills and nurturing leadership development for pervasive learning within higher education dCoPs.

Introduction

Whether a community is defined as a large number of individuals living in a given area, or characterized as a population of students in a classroom setting, communities are social constructs that reflect a fellowship of customs, characteristics, and shared identities with mutual goals. In addition, educational practices are the application of professional knowledge and skills employed in learning environments to attain learning environmental goals. The intersection of community and educational practices affords educational leaders with targeted proficiency for cultivating the shared achievement of educational accomplishments. The overarching goal is to not only employ practice within a community for improving educational outcomes, but to also transfer skills and inspire community through innovative practices, nurturing leadership for community to lead and take ownership.

Theoretical Background

A Community of Practice

Creating conditions for establishing a Community of Practice (CoP) is the actualized, intersectionality of embracing community and professional practice. A CoP affords individuals within a community an interactive, supportive atmosphere for sharing ideas, learning from one another, and reflecting on processes for generating knowledge and applying realizations for improved performance (Lesser & Storck, 2001). Individuals within a CoP are empowered by developing a sense of both individual and group identity as well as efficacy (Lesser & Storck, 2001; Polizzi et al., 2021).

In addition, establishing a CoP creates a network for individuals and groups within the communal nexus to influence positive outcomes for sustaining and improving characteristics meaningful and relevant to communal practice (Gherardi, 2009). A CoP and the networks that form are not limited in size and can range from internal

and external stakeholders within a learning organization to the teacher and students within a classroom setting. A CoP is dependent on the social interactions of networking individuals and reliant on experiential learning for reflection and social actualizations for knowledge attainment (Kolb, 2014; Kolb et al., 1984; Lesser & Storck, 2001; Vygotsky, 1978).

Digital Communal Learning

A CoP is not strictly limited to interactions among individuals in a face-to-face environment or an in-person classroom. As a result of ongoing technological advancements for communicating and sharing ideas, networking can take place both in-person and virtually for improving characteristics meaningful and relevant to communal practice among individuals within a CoP. An online, digital Community of Practice (dCoP) is a digital space where people with a common interest work together over time for sharing ideas, constructing knowledge, and can be incorporated into a classroom setting for networking (Kirschner & Lai, 2007). Employing dCoP classroom networks facilitates communications, collaboration, flexibility, and knowledge sharing among educators, potentially improving the use of technology in the classroom (Riverin & Stacey, 2008). Employing digital communications offers advantages, such as increased accessibility, information exchange, and forging connections for collaborating beyond face-to-face settings, leading to enhanced communications, collaboration, cooperative learning, and knowledge sharing (Horan & Wells, 2005; Oguz et al., 2010).

Students in higher education settings benefit from the utilization of a dCoP by gaining access to a virtual platform for independent and collaborative learning for enhancing educational experiences and fostering a sense of community and support among peers (Horan & Wells, 2005). Nizzolino and Canals (2021) propose the utilization of a Community of Inquiry (CoI) framework for dCoPs that is grounded in constructivism and outlines the essential elements of successful digital higher education learning by emphasizing cognitive presence, social presence, and teaching presence for collaboratively constructing and confirming meaning through discourse and reflection. Constructivism is a theory that proposes knowledge acquisition as a process of attainment that occurs through social settings and facilitated by social interactions for making connections that lead to the construction of knowledge (Vygotsky, 1978).

Artifacts and Digital Exemplars

The utilization of artifacts in higher education classroom settings has been somewhat understudied and largely focused on verbal interactions between students when examining artifacts as opposed to learner processes in making connections and constructing understanding. When employed in classroom settings, the utilization of artifacts serves as a form of visual literacy, providing students with visual depictions of relevant material being studied and supports shared learning and understanding (McDonald et al., 2005). The utilization of artifacts in higher education provides students with authentic, expert knowledge exemplars. Digital artifacts pertaining to instructional technology present and create a variety of expert knowledge for students to engage in an accessible manner, aiding in the understanding and retention of information (Ching, 2004). A CoP utilizes artifacts to influence teaching and learning practices as a result of interacting and reflecting on the artifacts being studied (Halverson, 2003). Likewise, a dCoP employs digital artifacts and also influences social capital. When professors utilize artifacts for reflective practice, they consider their own practice, which results in fostering trust and open discussions regarding instructional practices (Halverson, 2003).

In transdisciplinary learning, artifacts are essential as they act as concrete objects or symbols that aid in communication, collaboration, and the integration of knowledge among a variety of stakeholders, ultimately promoting the joint creation of solutions to sustainability issues (Barth et al., 2023). Artifacts can be used for teaching Science, Technology, Engineering, Art, and Mathematics (STEAM) by providing tangible examples that connect abstract concepts to real-world applications, fostering hands-on learning experiences, and promoting a deeper understanding of scientific principles through practical engagement (Jia et al., 2021).

Artifacts are also authentic materials or work products constructed by leaders, teachers, and students. The use of artifacts in dCoPs provides digital exemplars for repeatedly studying and reflecting for professional growth. Educator use of artifacts also creates transferable skills for supporting learners. Artifacts impact learning by presenting tangible and visual representations of concepts, making abstract ideas more accessible and relatable, thus enhancing understanding and engagement with the subject matter (Dell'Erba, 2019).

Intersections of STEAM

Interdisciplinary Leadership and Transdisciplinary Learning

Interdisciplinary leadership entails uniting individuals with diverse perspectives and methodologies from disparate disciplines and encouraging them to employ integrative thinking to tackle complex tasks or issues, fostering direction, alignment, communications, and integration (Bloomquist & Georges, 2022). Employing interdisciplinary leadership creates an environment conducive to the creation of new ideas as a result of diverse perspectives for scholarship. Creating conditions to foster scholarship through amalgamation results in integrated learning among scholarly educators through the process of combining divergent content for constructing real-world applications and promoting interdisciplinary collaboration (Liao, 2016). Employing interdisciplinary leadership naturally creates an atmosphere that supports interdisciplinary learning through the scaffolding of diverse disciplines for thematic problem-solving. When educators engage in interdisciplinary leadership planning, they also engage in conversations with one another as a result of pedagogical and methodological differences related to their individual content areas and disciplines.

While interdisciplinary leading, teaching, and learning provides perspective with respect to intersecting multiple disciplines, transdisciplinary learning utilizes those multiple perspectives for addressing a concept by students for connecting meaning and personalizing the learning. Transdisciplinary learning is multifaceted and includes aspects of inquiry, collaboration, and socialization, which also intersects with constructivism. Transdisciplinary education surpasses interdisciplinary methods by merging various disciplines to form a holistic comprehension of intricate problems, whereas interdisciplinary leadership concentrates on integrating diverse viewpoints within a team to tackle complex tasks or issues (Bloomquist & Georges, 2022). Transdisciplinary education integrates knowledge and methodologies from multiple disciplines to address complex real-world problems and encourages collaboration, critical thinking, and creativity, preparing students to tackle multifaceted challenges (Clark & Button, 2011).

Science, Technology, Engineering, and Mathematics (STEM) and STEAM learning through interdisciplinary leadership and transdisciplinary education creates the conditions for establishing a Transdisciplinary Community of Practice (TCoP). A TCoP comprises a diverse group of educators with varying experiences and expertise from different disciplines, methodologies, pedagogies, and societal domains who collaborate based on shared practices to experiment with ideas and address specific issues while striving to improve systems and processes (Barth et al., 2023). In addition, higher education transdisciplinary learning facilitates the development of job-ready skills in students and enhances student confidence in applying leadership techniques to real-life problems, thus providing students with a competitive advantage in the job market (Tasdemir & Gazo, 2020).

STEM to STEAM for Academic Achievement and Creativity

The impact of integrated learning on STEM to STEAM is significant as it supports the intersection of arts within STEM subjects, promoting interdisciplinary collaboration and the creation of real-world applications, elevating the importance of arts subjects in education as STEAM (Liao, 2016). The addition of art provides pathways for students to consider the aesthetics of science, technology, engineering, and mathematics. In addition, the arts intersects each discipline within STEAM for enhancing inquiry, inquisitiveness, and catalyzing critical-thinking to creative-thinking. Art is central in transdisciplinary education, as art transforms culture, inspires creative awareness, community engagement, and serves as a link for comprehending and implementing sustainable practices in science (Clark & Button, 2011).

The interdisciplinary and transdisciplinary nature of STEAM enables students to develop a broader understanding of complex issues and challenges, leading to improved problem-solving abilities and critical thinking skills (Allina, 2018). In addition, embedding art in STEM to STEAM supports the academic achievement of students as well as naturally creates opportunities for students to demonstrate creativity for design thinking. Design thinking is a philosophical approach for STEM to STEAM that affords learners opportunities to engage in authentic design processes. Design thinking supports students by fostering creative thinking, collaboration, and ownership of the learning, as well as by providing a framework for interdisciplinary and project-based learning experiences within the STEAM context (Henriksen, 2017).

Art is key for transdisciplinary learning as it fosters critical-thinking, creative-thinking and problem-solving skills, enabling students to connect their work to real-world settings and address complex issues that transcend

traditional disciplinary boundaries. A STEAM philosophical approach for supporting student learning provides creative cognitive and social, emotional opportunities for students to develop problem-solving skills in highly supportive interdisciplinary and transdisciplinary learning environments. In essence, intersecting art within and throughout transdisciplinary learning promotes innovative and holistic approaches to problem-solving (Liao, 2016).

STEAM and Adaptable Skills

The future of STEM and STEAM career growth is expected to emphasize the increasing importance of STEM-related transferable skills such as critical thinking, creative problem solving, design thinking, and collaborative teamwork, alongside STEM disciplinary knowledge in forms that are applicable in authentic settings (Tytler, 2020). STEAM is an important philosophical learning approach that creates a transdisciplinary space for fostering creativity, innovation, and problem-solving skills, preparing students to address 21st-century challenges and contribute to an innovative society (Liao, 2016). STEM and STEAM careers are projected to experience significant growth in the coming years. Providing students with innovative, creative STEAM programming and learning spaces is a catalyst for promoting STEAM career considerations in learners. The expansion of careers in STEM (and STEAM) is anticipated to occur and continue as a result of technological progress, innovation, and the rising need for skilled individuals in science, technology, engineering, and mathematics disciplines (Fry et al., 2021).

Preparing students with STEAM skills provides learners with generational abilities they can employ in critical STEAM-related careers. The Bureau of Labor Statistics (BLS) anticipates an 8.8% rise in STEM employment from 2018 through 2028, in contrast to a 5% increase in non-STEM employment during the same period (Jiang, 2021). Establishing a dCoP for experienced and preservice teachers engaged in higher education learning environments provides transferable interdisciplinary and transdisciplinary skills teachers can employ for better supporting students. Developing transferable skills for students is critical for fostering student growth. Transdisciplinary training in higher education equips educators with the knowledge and skills needed post-college for competency and workforce-ready preparedness (Tasdemir & Gazo, 2020). The establishment and utilization of a dCoP creates an in-person and virtual environment for developing interdisciplinary and transdisciplinary skills for supporting STEAM education as well as the social, emotional needs of all learners.

STEAM for Academic Achievement and Social Capital

Intersections of art into STEM education encourages the development of empathy, collaboration, and communication skills, which are crucial for thriving in STEM-related fields (Amalu et al., 2023). In addition, the intersection of a dCoP in preservice and experienced teacher, higher education learning environments facilitates conversations between educators from multiple disciplines, resulting in increased empathy for student learners. The intersection of STEAM and dCoPs affords authentic constructivist, communicative, social, emotional learning environments for both educators and students. STEAM facilitates social emotional learning by affording students pathways for cultivating resilience, teamwork, problem-solving, and communication skills through practical, interdisciplinary tasks (Rikoon et al., 2018). Providing students with cognitive, social, emotional development creates a holistic learning environment for supporting the academic and social, emotional learning needs of all learners.

Figure 1. Intersections of STEAM

Emotions impact STEAM learning and interests which affects student engagement and performance and offers new ways to engage emotions by recognizing and dealing with the emotional side of learning (Liao et al., 2022; Steele & Ashworth, 2018). When students are emotionally supported, they are more likely to engage in constructivist learning opportunities, facilitating curiosities about learning and ownership of the learning. Student curiosities are piqued by the interdisciplinary and transdisciplinary construct of STEAM learning, which results in positive emotional responses commonly encountered during problem-solving and decision-making in STEAM education (Liao et al., 2022). The interdisciplinary and transdisciplinary nature of STEAM affords students with diverse perspectives for critical-thinking, creative-thinking, collaborative learning, personalized learning, and forging adaptable skills (Figure 1).

Pervasive Learning and Leadership Nurturing

Leadership nurturing inspires innovation by empowering individuals to enhance their skills, fostering a culture of collaboration, and promoting the generation of new ideas (Owusu-Agyeman, 2021). Rather than adhering to traditional leadership models that prioritize skills and tactics, leadership cultivation must emphasize qualities such as creativity, innovation, and a systemic understanding of leadership (Montgomery, 2020). Establishing and employing a dCoP for preservice and experienced teachers in higher education programs facilitates transformational leadership skills development for improving professional practice. Cultivating leadership through a transformation lens is a leadership style that has a notable positive effect on teacher creativity, subsequently influencing students' intelligence and overall teacher performance (Belawati, 2019).

The most effective methods for fostering leadership development include instruction in leadership theories and concepts, coaching in leadership abilities, and cultivation of leadership experience, which affords a holistic strategy for acquiring the knowledge, skills, and hands-on experience essential for successful leadership (Brooks et al., 2019). A dCoP provides educators with authentic artifacts they can explore for transforming their own innovative educational settings for the students they lead. Innovation is fostered through transformational leadership that facilitates active involvement, motivation, effective communications, and decision-making among educators (Owusu-Agyeman, 2021). The use of artifacts in a dCoP is a contemporary approach for cultivating leadership and facilitating pervasive learning among educators through the use of digital media. Transformation is key for empowering teachers, cultivating leadership and must consider the changing landscape of academia, demographics, technological advancements (Belawati, 2019; Montgomery, 2020).

Intersections of Cybernetics

Cybernetic Mindset and Feedback Loops

Cybernetics is a multidisciplinary field that offers an understanding of how people and technology act as complex systems navigating their surroundings (Tilak & Glassman, 2022). The communicative intersections of living and nonliving things are interactions that provide perspective regarding the ways entities adapt to their surroundings. Cybernetics examines communications in animate and inanimate objects with an emphasis on the interaction between observers and systems (Murray, 2006). The ways humans and technologies process information affects the ways information is applied within environments. Cybernetics affords educational and pedagogical technologies valuable insights into the fundamental principles of control and information exchange in machines, living organisms, and society (Gushchin & Divakova, 2015). Utilizing technology as a platform to examine educational phenomena within a CoP provides a medium for considering and reflecting on leading, teaching, and learning with respect to STEAM education and educational leadership. The intersection of cybernetics and education are enhanced through the use of digital tools and platforms for creating adaptive and interactive learning experiences (Murray, 2006).

Constructivist philosophy and cybernetics intersect as they both center on learning, adaptation, and the interaction between individuals and their environment as an active process of constructing knowledge through experiences (Tilak, 2023). Utilizing a digital platform for examining digital artifacts provides a constructivist environment for the intersection of human cognition and reflection alongside a technological framework for presenting phenomena and connecting understanding. Vygotsky's concepts regarding the connections between action and thinking are pertinent to cybernetics due to their emphasis on the interplay between human cognition and behavior, aligning with the cybernetic framework's focus on understanding individuals' interactions and adaptation to their surroundings (Tilak & Glassman, 2022).

Both constructivism and cybernetics emphasize the dynamic and recursive relationships between individuals and their environment, and they share a focus on understanding learning as an emergent phenomenon (Tilak, 2023). Moreover, leading a dCoP through a cybernetic mindset provides opportunities to explore digital artifacts in an interactive manner for authentic interactive reflection and future applications for improving educational environments. Employing a cybernetic lens enables the analysis of how digital educational technologies can optimize pedagogical processes by understanding the interactions between digital learning, individuals, and the utilization of artifacts (Gushchin & Divakova, 2015).

Employing a cybernetic mindset also creates a contemporary digital environment for nurturing teacher agency for pervasive learning. Teacher agency refers to the ability of teachers to function autonomously for initiating and leading change within educational systems and learning organizations. Teacher agency enables educators to play a decision-making role in creating positive changes, introducing innovative teaching methods, and adjusting to the diverse needs of students, thereby cultivating a more dynamic and efficient learning environment (Lee, 2021). In classrooms and educational settings, cybernetics provides a number of advantages, including guidance and navigation, integration of constructivism, feedback mechanisms, and adaptability and flexibility (Grover, 2016).

The examination of artifacts through a digital platform creates opportunities for educators to make connections, reflect on understanding, and develop naturally recurring feedback loops for internal and group discussions regarding perceptions for active ownership of learning. Employing a digital platform facilitates interactive and personalized feedback loops, which provides continuous learning and adjustments of learning processes (Chen & Cao, 2014). These types of cybernetic feedback loops facilitate the construction of knowledge through reflection, discussions, and affirmation of understanding on environments for both teacher and learner agency. Cybernetics enhances educational design and the efficacy of digital learning environments through constructivist pedagogical processes (Abdulwahed et al., 2008).

Von Glasersfeld (2019) describes cybernetics as a regulatory functions approach that provides insight with respect to learner experiences and the construction of knowledge. This is significant as it offers a structure for comprehending how individuals engage with their surroundings, acquire knowledge from their experiences, and cultivate cognitive abilities (Abdulwahed et al., 2008; Ole & Gallos, 2023; Von Glasersfeld, 2019). A cybernetic CoP is empowered by digital experiential learning that is highly collaborative and interactive for connecting cognitive and emotive aspects of learning environments. Intersections of cognition, learning, instructional design, and cybernetics provide meaningful learning experiences in interactive, digital learning environments (Scott, 2007). Cybernetic approaches support digital learning environments by prioritizing efficient communications, collaborative learning, and a reexamination of conventional teaching techniques (Baron, 2015).

The construction of knowledge through a cybernetic mindset affords dCoP with contemporary settings for examining educational, environmental phenomena for transformational leadership. Intersections between educational settings and individuals provides a framework for understanding how teachers' agency can contribute to systemic change and knowledge production within educational settings (Lee, 2021). A major goal of all educators is to improve learning for individuals and the environmental settings where learning takes place. Intersections of cybernetics, digital learning, teacher agency, and the personal experiences of individuals is significant as it underscores the necessity of creating learning tools and environments that are in harmony with how individuals naturally interact and adapt, ultimately improving the efficacy of the learning process (Tilak & Glassman, 2022). The intersections of digital learning, teacher agency, and the personal experiences of individuals is a principal component of a cybernetic dCoP.

Conceptual Framework

This study introduces a holistic model aimed at improving educational approaches and utilizing artifacts through tiered intersections of technology for establishing an innovative, communicative, and reflective digital Community of Practice (dCoP). The construct presented incorporates interdisciplinary and transdisciplinary STEAM concepts while advocating for the utilization of digital technologies for providing a virtual communal space for educators to exemplify and explore digital artifacts for personalized and communal learning. STEAM education has been shown to be a leading area for fostering transferable skills in learners, as future global career growth is largely situated within STEAM professions. Utilizing digital exemplars provides a unique space for educators to reflect on current areas of need for facilitating STEAM education, considering the social, emotional

needs of all learners, and also cogitating the cultivation of innovative STEAM programmatic offerings for careers that do not yet exist.

In concert, the intersectionalities of these qualities form the basis of a conceptual framework that forge a proposed theoretical *Cybernetic Three-Realm Model for STEAM and Leadership Nurturing.* The researcher provides an overview of the theoretical model and authentic application within a dCoP for use with graduate and doctoral students in higher education. The theoretical *Cybernetic Three-Realm Model for STEAM and Leadership Nurturing* addresses (1) Scholarship of Teaching and Learning (SoTL), (2) digital artifacts presentation through storytelling, and (3) considerations for addressing the social, emotional needs of learners through multiple modalities for learning. The *Cybernetic Three-Realm Theoretical Model* provides a tangible framework for use in higher education dCoPs (Figure 2).

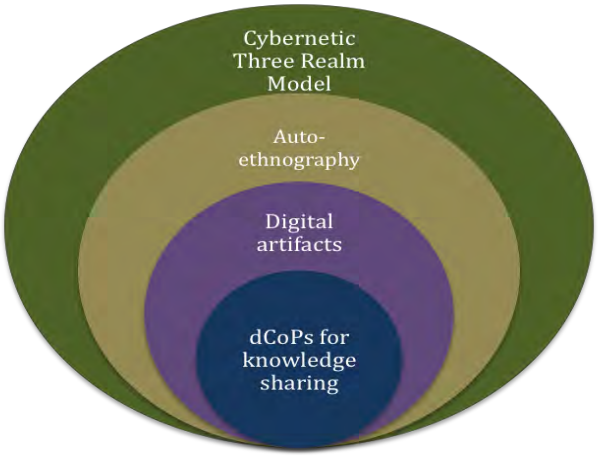

Figure 2. Conceptual framework

Method

Portraiture for Painting Stories

Portraiture is a research methodology that was developed in the late 1990s and includes aspects of narration, ethnography, case study, and phenomenology for examining the shared experiences of individuals (Lawrence-Lightfoot & Davis, 1997). Portraiture methodology allows for creating an atmosphere for reflecting on identity and understanding within the boundaries of experiences (Gaztambide-Fernández et al., 2011; Lawrence-Lightfoot, 2005; Quigley et al., 2015). Portraiture blends art and science through empirical aspects of inquiry with descriptive, aesthetic properties. In addition, a portraiture approach is beneficial for creating autoethnographic narratives regarding phenomena, as it allows for the researcher's voice to be intertwined within descriptive analysis and perceptions of lived experiences (Golsteijn & Wright, 2013; Hackmann, 2002).

Autoethnography

Autoethnography is a methodological descriptor for a form of self-critical reflective writing that embeds the author's life experiences to depict significant aspects of life within specific political, social, economic, and cultural contexts, with the aim of driving change and improvement (Belbase et al., 2008). Employing autoethnography incorporates perspective and reflection for immersing experiences while observing phenomena. The researcher emphasizes the use of autoethnography for creating an innovative, contemporary approach with digital storytelling for presenting authentic educational experiences in an innovative manner to elicit pervasive learning in students.

Autoethnography and storytelling enable individuals to engage in critical reflection on their experiences and delve into the socio-cultural dimensions of identity formation, potentially fostering societal transformation (Austin & Hickey, 2007). The utilization of digital artifacts provides authentic exemplars that educational leaders can utilize for exploration and reflective practice for supporting a culture for learning. Artifacts are important resources that present experiences and knowledge that emphasize the significance of personal experiences and perspectives (Canagarajah, 2012).

Intersections of digital autoethnography, digital storytelling, and the use of digital artifacts empowers members of a dCoP to observe authentic educational exemplars for critical self-reflection and considering how to employ narratives for actualizing STEAM education and leading schools and learning organizations. Storytelling and autoethnography are approaches that link individual experiences to broader cultural and socio-cultural identities for facilitating critical introspection and transformation (Austin & Hickey, 2007).

Digital Storytelling

Employing portraiture methodology allows for the utilization of digital autoethnography via storytelling. Intersections of interdisciplinary and transdisciplinary leading, teaching, and learning through a digital autoethnographic, storytelling lens focuses the unification of educational practice with communications and information technologies. Nishioka (2016) recommends the use of Information and Communication Technologies (ICT) and Web 2.0-based digital platforms and applications that facilitate interactive and collaborative online engagement for enabling users to create, share, and interact with content for facilitating language learning through digital storytelling.

Intersectionalities of ICT, digital educational methodologies, and pedagogy results in not only the formation of a functional dCoP, but also actualizes a variety of contemporary educational technological skills. The construction of a digital platform, webspace, or site for a dCoP to examine evolving artifacts is an innovative approach for intersecting learner experiences, technology, digital skills development, and reflection for ownership of the learning. Çetin (2021) identified a variety of new literacy skills, including digital, global, technology, visual, and information literacy, that are critical for learners to proficiently understand, assess, and generate information in a modern, interconnected, and technologically advanced environment. A dCoP realizes the development of these contemporary skills (Figure 3).

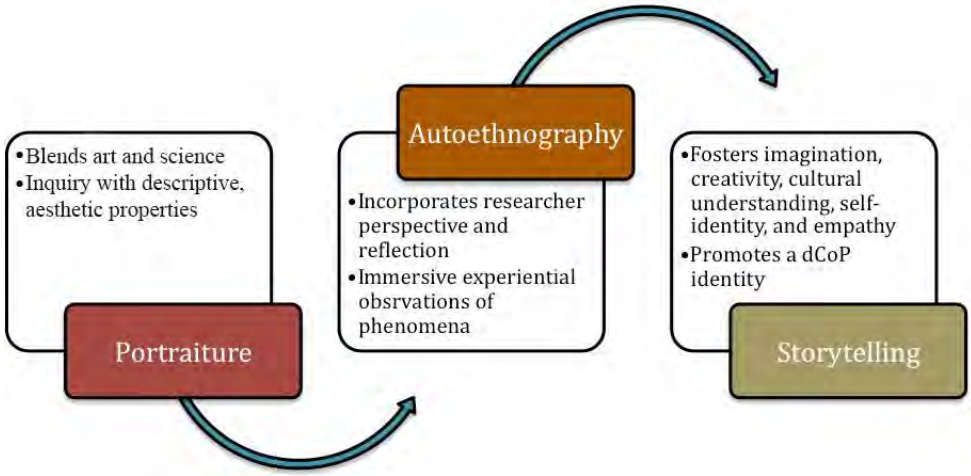

Figure 3. Methodological intersections for cybernetic dCoPs

Results and Analysis

Cybernetic Three-Realm Model for STEAM and Leadership Nurturing

Utilizing digital autoethnography and storytelling for establishing a digital Community of Practice (dCoP) provides both a digital and in-person network for students to explore and share ideas for reflection, resulting in pervasive learning and leadership nurturing. The formation of a dCoP also results in self-identity and communal identity for supporting practice. In tandem, these approaches create a platform and a forum for supporting STEAM education, leadership nurturing, and pervasive learning in supporting meaningful, relevant cognitive and social, emotional supports. Intersections of cybernetics, leading, teaching, and learning empower dCoPs to utilize exemplars in a digital environment for interactive critical reflection, questioning, and developing socio-cultural dimensions of identity information through shared journeys. Cybernetic leading, teaching, and learning creates conditions for supporting meaningful STEAM, leadership nurturing, and a cybernetic mindset for pervasive learning.

Applying a cybernetic mindset in the development of a cybernetic dCoP for the examination of digital artifacts with education students in higher education results in three significant realms of a cybernetic learning environment. Each realm serves as a domain or sphere of knowledge within cybernetic educational settings. The *Cybernetic Three-Realm Theoretical Model* juxtaposes the utilization and input of digital artifacts within a cybernetic framework with the resulting outputs for supporting STEAM education and educational leadership nurturing. When considering each realm, it is important to first consider the role of cybernetics. In the *Cybernetic Three-Realm Theoretical Model*, cybernetics is analogous to the brushstrokes of paint from the artist's palette to canvas. Cybernetic brushstrokes are the medium for moving paint from palette to canvas, and as such, a cybernetic brushstroke analogy is present within each realm for creating an aesthetic, scientific perspective with respect to the intersections of cybernetics and education (Figure 4).

Figure 4. Components of the cybernetic three realm theoretical model

The *Cybernetic Three-Realm Theoretical Model* is a portrait of cybernetic brushstrokes upon:

1. *A Canvas for Scholarship of Teaching and Learning*: A Scholarship of Teaching and Learning (SoTL) results and is directly connected to preparing teachers and leaders to meet real-world problems and issues with sophisticated, multi-dimensional solutions.
2. *An Artist's Palette for Authentic Artifacts*. The artist's palette serves as a storyteller's forum for presenting the blending of disparate disciplines to promote interdisciplinary, innovative instructional design (Smyth & Carless, 2021).
3. *The Paints of Modalities for Learning*: The experiences presented results in the creation and establishment of blended, welcoming, innovative learning environments that consider the social, emotional needs of learners, and provide multiple modalities for learning (To & Carless, 2016).

Cybernetic Brushstrokes

A Canvas for Scholarship of Teaching and Learning

Cybernetics affords learners within a dCoP opportunities to construct knowledge through the use of technology for processing *information of thought* through reflection. Utilizing a digital environment for preservice and experienced educators to examine digital, authentic artifacts nurtures teacher agency for pervasive learning. As a result of intersecting phenomena in a dCoP, a Scholarship of Teaching and Learning (SoTL) develops. If we envision cybernetics as both a scientific and artistic brushstroke, a SoTL is the intersection of brushstroke and canvas for equipping educators and leaders to address real-world problems and challenges using advanced, multi-faceted solutions. The SoTL is a process of constructing knowledge through reflection on teaching experiences and educational theory (Kreber, 2006; Prosser, 2008). When teachers and leaders develop and employ a SoTL, they connect knowledge for experiential application with multiple pathways for solution-finding.

The SoTL is the first realm of the *Cybernetic Three-Realm Theoretical Model* for use in higher education to augment developing educator learning through a student-centered learning environment. High-performing educators employ the SoTL to enhance student learning through scholarly measures and a student-centered philosophical design (Benjamin, 2000; Trigwell, 2013). Students benefit from the SoTL as a result of enhanced learning experiences, a supportive learning environment, and the implementation of student-centered teaching and learning.

Moreover, the SoTL is a pedagogical intersection of scholarship, student-centered learning, and partnering with scholars for transforming learning from brush to canvas. The SoTL is significant as it seeks to address the unequal emphasis on teaching and research, improve the standard of student learning, and engage scholars as

active participants in the learning process, ultimately enhancing the overall educational experience (Almeida, 2010). The manner in which learners process information impacts the ways in which digital artifacts will be employed in future learning environments. A SoTL creates an atmosphere for processing authentic artifacts through scholarly reflection and values for contributing to the teaching profession. Prioritizing authentic learning supports students' intellectual, academic, personal, and interpersonal development for a SoTL (Benjamin, 2000; Kreber, 2013).

An Artist's Palette for Authentic Artifacts

Employing a cybernetic mindset affords educators opportunities to engage in authentic, digital autoethnographic storytelling through the utilization of artifacts and reflective analysis. Applying digital autoethnography through storytelling allows for the presentation of artifacts for self-identity and a dCoP identity. Storytelling facilitates teachers connecting personal experiences to broader educational issues, establishing shared norms of effective teaching, and fostering a collaborative learning environment (Shank, 2006). With each cybernetic brushstroke, a dCoP scientifically examines artifacts of the artist's palette for finding ways to improve education.

Authentic artifacts are the medium of the artist's palette, and the artist's palette is the second realm of the *Cybernetic Three-Realm Theoretical Model*. Authentic artifacts of the artist's palette are employed for examining phenomena and are grounded in constructivist, experiential learning. An autoethnographic, storyteller's approach assists educators in personalizing and constructing understanding by experientially studying intersections of individuals and the environment. Digital storytelling empowers personal narratives by enabling digital educators opportunities to reflect on and share their experiences, thereby linking digital storytelling to personal storytelling for hands-on, experiential learning, reflection, and exploration (Skouge & Rao, 2009).

A paletted, artistic approach is particularly helpful for supporting STEAM education, leadership nurturing, and pervasive learning as it is relational-rich and connects cognitive, social, and emotional constructs of a dCoP. In higher education settings, artifacts can be employed to communicate and shape various representations of expert knowledge for students, creating trust, and social capital within the dCoP (Ching et al., 2004; Halverson, 2003). Moreover, interdisciplinary intersectionalities of disparate knowledge and methods through transdisciplinary approaches go beyond disciplinary boundaries to integrate knowledge and methods in a way that transcends traditional academic disciplines, focusing on addressing complex real-world problems (Liao, 2016). The artist's palette promotes interactive critical reflection, questioning, and developing socio-cultural dimensions of identity information through shared journeys. The artist's palette is a storyteller's forum for presenting the blending of disparate disciplines to promote interdisciplinary, transdisciplinary innovative instructional design

The Paints of Modalities for Learning

Experientially-derived, constructed knowledge consists of many shades, hues, and tones within a cybernetic realm. Much like the philosophical blended construct of leading and teaching STEAM philosophical pedagogy, learning, too, is multivariate and -faceted. Multimodal learning is a pedagogical approach that facilitates the presentation of digital artifacts through various sensory modes, including visual, aural, and textural forms (Bouchey et al., 2021). Technology enables the creation of innovative learning modalities that can cater to a variety of learning styles for personalized, meaningful learning that provides students with control over how they access artifacts and provides experiential choice regarding learning awareness (Irvine et al., 2013; Stoilescu, 2008). The establishment of a dCoP provides multiple modes of learning and is a component of the cybernetic schema.

The paints of modalities is the third realm of the *Cybernetic Three-Realm Theoretical Model*. When contemplating this realm for supporting STEAM and nurturing leadership, consider cybernetics the brush that utilizes individual spectra of paint for learning. Each color of paint varies by shade, hue, and tone and possesses properties and potential for creating portraits of understanding. The needs, qualities, and gifts of each learner vary and providing modalities of learning presents students with opportunities to examine and express phenomena according to their cognitive styles. The blending of paints also results in new colors that did not previously exist. Educational institutions must be innovative-minded and adjust to meet the expectations of 21st-century learners by affording modalities of learning for taking into account students' individual learning styles and the ways students interact with artifacts that match their personal preferences and needs (Irvine et al.,

2013). A multimodal inclusive approach nurtures a feeling of belonging and inclusivity within a dCoP, fostering a supportive and cooperative learning atmosphere that meets the social needs of all learners (Galvis, 2018; Irvine et al., 2013; Stoilescu, 2008)

Student interactions within a dCoP blend cybernetic spectra that also influence motivation and ownership of the learning. Blended learning programs are shaped by their social and motivational-cognitive characteristics, impacting their learning and satisfaction (Diep et al., 2017). A dCoP not only needs to consider students' varied approaches for cognitive learning, but must also provide modalities of learning to support the social, emotional needs of all learners. It is imperative that educators plan, develop, and establish a supportive and engaging atmosphere that affords learners with multiple modes of learning for diverse cognitive and social needs. (Diep et al., 2017; Stoilescu, 2008). Multimodal learning experiences result in the creation and establishment of a blended, welcoming, innovative dCoP. The paints of modalities provide multivariate cognitive pathways for supporting the social, emotional needs of learners.

Discussion

It is essential to transform the development of leaders and the practice of leadership to effectively address the evolving challenges of the future (Montgomery, 2020). The establishment of a cybernetic dCoP provides an innovative learning environment for nurturing STEAM and leadership development for pervasive learning among education students. The establishment of a cybernetic dCoP also provides for the development of an evolving, reflective atmosphere that empowers and personalizes learning for transforming learning environments.

A cybernetic dCoP is a construct that promotes leadership development and transformational leadership in teachers. Transformational leadership has a significant and positive effect on the empowerment and creativity of teachers (Belawati et al., 2019). Transformational leadership fosters leadership in others by motivating and challenging individuals to enhance their skills, promoting a sense of purpose, and encouraging active involvement in decision-making (Owusu-Agyeman, 2021). Leadership nurturing provides future leaders with skills they can employ for leading schools, communities, and improving teaching and learning.

The *Cybernetic Three-Realm Model for STEAM and Leadership Nurturing* presented in this study provides an innovative approach for intersecting community-building with transferable skills from teachers to students in STEAM education and for leadership development in higher education. In an effort to improve instructional STEAM practices and nurture leadership abilities in future educators, schools of higher education should consider the establishment of digital Communities of Practice (dCoPs) as platforms for eliciting knowledge sharing, collaborative discourse, and reflection. Schools of higher education should also consider placing particular emphasis on the transference of interdisciplinary and transdisciplinary skills through dCoPs for the development of STEAM learning environments that embrace critical-thinking, creative thinking, and support the social, emotional, and behavioral development of all learners for problem-solving.

Conclusion

A dCoP is a digital space for knowledge sharing, exchanging ideas, and collaboratively constructing and confirming meaning through discourse and reflection. Utilizing artifacts in higher education provides preservice and experienced educators with real-world, expert knowledge for constructing new knowledge as well as constructing social capital. Utilizing artifacts in STEAM education provides concrete examples that connect abstract concepts to real-world applications. STEAM education is strengthened through the use of interdisciplinary leadership and teaching that unites multiple disciplines with diverse perspectives and methodologies through a transformational lens that is multifaceted and includes aspects of inquiry, collaboration, socialization, experiential learning, and constructivism. While many schools and learning institutions employ a STEM philosophy for uniting disparate disciplines, a STEAM philosophy intersects art across each discipline for enhancing inquiry, inquisitiveness, and catalyzing critical-thinking to creative-thinking.

A dCoP capitalizes on the social, emotional skills development STEAM education affords in addition to promoting critical-thinking and creative-thinking among learners. Future careers in areas of STEAM education are projected to grow at nearly twice the rate of non-STEM and -STEAM career pathways. Establishing a dCoP

for experienced and preservice teachers engaged in higher education learning environments provides transferable interdisciplinary and transdisciplinary skills teachers can pass on to students for supporting STEAM learning and future STEM and STEAM career opportunities. STEAM facilitates social, emotional learning and the intersections of STEAM and dCoPs provide authentic experiential, constructivist, communicative, social, emotional learning environments for both educators and students. Establishing and employing a dCoP for preservice and experienced teachers in higher education programs facilitates transformational leadership skills for improving professional practice.

Employing portraiture philosophy through an autoethnographic methodology creates an interactive, ongoing research forum for presenting the shared journeys of meaningful educational experiences. In higher education learning for preservice and experienced teachers, preserving and retrieving digital artifacts pertaining to STEAM education, curricular design, instructional leadership, and educational leadership empowers educators in examining the shared journeys of educational experiences and personalizes reflective processes. Employing storytelling through digital autoethnography enables a dCoP to interact with artifacts for critical reflection, questioning shared journeys, and forging socio-cultural dimensions of identity information.

Cybernetics examines communicative intersections of living and nonliving entities and provides perspective regarding the ways humans and digital technologies adapt to their surroundings. Developing and establishing a dCoP with a cybernetic mindset provides a medium for nurturing STEAM skill set development in educators and nurtures leadership and pervasive learning. The researcher presents a theoretical *Cybernetic Three-Realm Theoretical Model* that addresses (1) Scholarship of Teaching and Learning (SoTL), (2) digital artifacts presentation through storytelling, and (3) considerations for addressing the social, emotional needs of learners through multiple modalities for learning. In the *Cybernetic Three-Realm Theoretical Model*, cybernetics is analogous to the brushstrokes of paint from the artist's palette to canvas. Cybernetic brushstrokes are the medium for moving paint from palette to canvas, creating an aesthetic, scientific perspective with respect to the intersections of cybernetics and education. The *Cybernetic Three-Realm Model* for STEAM and Leadership Nurturing provides a tangible framework for use in higher education dCoPs.

Recommendations

Implementation of dCoPs necessitates the incorporation of artifacts to better support and motivate preservice and experienced educators for connecting abstract concepts with real-world applications, thereby fostering a more immersive and applicable learning environment. Intersections of artifacts, communications, and technology within a dCoP aligns with the overarching philosophical construct of STEAM for leadership nurturing and is a holistic technique that not only encourages inquiry, critical-thinking, and creative-thinking but also cultivates collaboration among a dCoP through the implementation of interdisciplinary leadership and teaching methodologies. In addition, prioritizing social and emotional learning in the context of STEAM education is paramount and is highly recommended for supporting all learners. Emphasizing social capital-building and emotive connections to learning significantly contributes to the cultivation of critical-thinking, creative-thinking, and skills for use in future STEAM careers, which are anticipated to experience continued growth and demand for decades.

When developing and delivering a dCoP in higher education settings, it is recommended that professors integrate portraiture, autoethnographic methodology through storytelling for the establishment of a highly personalized, reflective, and continuous research forum. A dCoP platform facilitates the exchange of meaningful educational experiences, the preservation of evolving digital artifacts, and the socio-cultural personalization of reflective processes. Additionally, it is recommended that the presentation of artifacts in a dCoP is done so through the intersection of storytelling and digital autoethnography for experiential sensemaking and relational-richness.

Lastly, it is recommended that higher education dCoPs adopt the *Cybernetic Three-Realm Model* as introduced by the researcher. The model presented by the researcher is a highly-structured framework for addressing the Scholarship of Teaching and Learning, the presentation of digital artifacts through storytelling, and considerations for attending to the diverse cognitive, social, and emotional needs of learners through modalities of learning. Adoption of the *Cybernetic Three-Realm Model* provides a tangible guide for educators, enhancing teaching practices and leadership abilities for improving educational outcomes for all learners.

Scientific Ethics Declaration

The author declares that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the author.

References

Abdulwahed, M., Nagy, Z., & Blanchard, R. (2008). *Constructivist project based learning design, a cybernetics approach*. file:///C:/Users/pc/Downloads/Publication%207%20.pdf

Allina, B. (2018). The development of STEAM educational policy to promote student creativity and social empowerment. *Arts Education Policy Review*, *119*(2), 77-87. https://doi.org/10.1080/10632913.2017.1296392

Almeida, P. A. (2010). Scholarship of teaching and learning: An overview. *Journal of the World Universities Forum*, *3*(2), 143-154. https://doi.org/10.18848/1835-2030/CGP/v03i02/56669

Amalu, E. H., Short, M., Chong, P. L., Hughes, D. J., Adebayo, D. S., Tchuenbou-Magaia, F., ... & Ekere, N. N. (2023). Critical skills needs and challenges for STEM/STEAM graduates increased employability and entrepreneurship in the solar energy sector. *Renewable and Sustainable Energy Reviews*, *187*, 113776. https://doi.org/10.1016/j.rser.2023.113776

Austin, J., & Hickey, A. (2007). Autoethnography and teacher development. *International Journal of Interdisciplinary Social Sciences*, *2*(2), 369-378. https://doi.org/10.18848/1833-1882/CGP/v02i02/52189

Baron, P. (2015). Reformulating the responsibilities of the actors in the classroom: A cybernetic perspective. In *Proceedings of the 3rd Biennial Conference of the South African Society for Engineering Education. ISBN9780620647632*.

Barth, M., Jiménez-Aceituno, A., Lam, D. P., Bürgener, L., & Lang, D. J. (2023). Transdisciplinary learning as a key leverage for sustainability transformations. *Current Opinion in Environmental Sustainability*, *64*, 101361. https://doi.org/10.1016/j.cosust.2023.101361

Belawati, F. E., Setyadi, D., & Hendri, M. I. (2019). Effect of transformational leadership style and knowledge management on organizational innovation through empowerment, member creativity and learning organization. *Journal of Arts and Humanities*, *8*(8), 01-16. https://doi.org/10.18533/journal.v8i8.1699

Belbase, S., Luitel, B., & Taylor, P. (2008). Autoethnography: A method of research and teaching for transformative education. *Journal of Education and Research*, *1*(1), 86-95. https://doi.org/10.3126/jer.v1i0.7955

Benjamin, J. (2000). The scholarship of teaching in teams: What does it look like in practice?. *Higher Education Research & Development*, *19*(2), 191-204. https://doi.org/10.1080/072943600445646

Bloomquist, C. D., & Georges, L. (2022). Interdisciplinary leadership: A leadership development model for scholar-practitioners. *Journal of Leadership Education*, *21*(4). https://doi.org/10.12806/V21/I4/A4

Bouchey, B., Castek, J., & Thygeson, J. (2021). Multimodal learning. *Innovative Learning Environments in STEM Higher Education: Opportunities, Challenges, and Looking Forward*, 35-54. https://doi.org/10.1007/978-3-030-58948-6

Brooks, E., Brant, J., & Lamb, M. (2019). How can universities cultivate leaders of character? Insights from a leadership and character development program at the University of Oxford. *International Journal of Ethics Education*, *4*(2), 167-182. https://doi.org/10.1007/s40889-019-00075-x

Canagarajah, A. S. (2012). Teacher development in a global profession: An autoethnography. *Tesol Quarterly*, *46*(2), 258-279. https://doi.org/10.1002/tesq.18

Çetin, E. (2021). Digital storytelling in teacher education and its effect on the digital literacy of pre-service teachers. *Thinking Skills and Creativity*, *39*, 100760. https://doi.org/10.1016/j.tsc.2020.100760

Chen, Y., & Cao, R. (2014). Conceptualization of assessment as a formative system in teaching and learning: A cybernetic model. *Studies in Literature and Language*, *9*(1), 27. http://dx.doi.org/10.3968/4193

Ching, C. C., Levin, J. A., & Parisi, J. (2004). Classroom artifacts: Merging the physicality, technology and pedagogy of higher education. *Education, Communication & Information*, *4*(2-3), 221-235. https://doi.org/10.1080/14636310412331304681

Clark, B., & Button, C. (2011). Sustainability transdisciplinary education model: Interface of arts, science, and community (STEM). *International Journal of Sustainability in Higher Education*, *12*(1), 41-54. https://doi.org/10.1108/14676371111098294

Dell'Erba, M. (2019). Preparing Students for Learning, Work and Life through STEAM Education. Policy Brief. *Education Commission of the States*.

Diep, A. N., Zhu, C., Struyven, K., & Blieck, Y. (2017). Who or what contributes to student satisfaction in different blended learning modalities?. *British Journal of Educational Technology, 48*(2), 473-489. https://doi.org/10.1111/bjet.12431

Feder, T. (2022). The US is in dire need of STEM teachers. *Physics Today*, *75*(3), 25-27. https://doi.org/10.1063/PT.3.4959

Fry, R., Kennedy, B., & Funk, C. (2021). STEM jobs see uneven progress in increasing gender, racial and ethnic diversity. *Pew Research Center*, 1-28.

Galvis, Á. H. (2018). Supporting decision-making processes on blended learning in higher education: literature and good practices review. *International Journal of Educational Technology in Higher Education*, *15*(1), 1-38. https://doi.org/10.1186/s41239-018-0106-1

Gaztambide-Fernández, R., Cairns, K., Kawashima, Y., Menna, L., & VanderDussen, E. (2011). Portraiture as pedagogy: Learning research through the exploration of context and methodology. *International Journal of Education & the Arts*, *12*(4), 1-29.

Gherardi, S. (2009). *Community of practice or practices of a community*. The Sage Handbook of Management Learning, Education, and Development, 514-530.

Golsteijn, C., & Wright, S. (2013, September). Using narrative research and portraiture to inform design research. In *IFIP Conference on Human-Computer Interaction* (pp. 298-315). Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-40477-1_19

Grover, V. K. (2016). Classroom cybernetics: An approach for effective and efficient classroom teaching. *International Journal of Research in Advent Technology*, *4*(1), 45-52.

Gushchin, A., & Divakova, M. (2015). Trends of e-education in the context of cybernetics laws. *Procedia-Social and Behavioral Sciences*, *214*, 890-896.https://doi.org/10.1016/j.sbspro.2015.11.747

Hackmann, D. G. (2010, November). Using portraiture in educational leadership research. *International journal of leadership in education*, *5*(1), 51-60. https://doi.org/10.1080/13603120110057109

Halverson, R. R. (2003). Systems of practice: How leaders use artifacts to create professional community in schools. *Education Policy Analysis Archives*, *11*, 37. https://doi.org/10.14507/epaa.v11n37.2003

Henriksen, D. (2017). Creating STEAM with design thinking: Beyond STEM and arts integration. *The STEAM Journal*, *3*(1), 11. https://doi.org/10.5642/steam.20170301.11

Horan, T., & Wells, K. (2005). Digital communities of practice: Investigation of actionable knowledge for local information networks. *Knowledge, Technology & Policy*, *18*(1), 27-42. https://doi.org/10.1007/s12130-005-1014-y

Irvine, V., Code, J., & Richards, L. (2013). Realigning higher education for the 21st century learner through multi-access learning. *Journal of Online Learning and Teaching*, *9*(2), 172.

Jia, Y., Zhou, B., & Zheng, X. (2021). A curriculum integrating STEAM and maker education promotes pupils' learning motivation, self-efficacy, and interdisciplinary knowledge acquisition. *Frontiers in Psychology*, *12*, 725525. https://doi.org/10.3389/fpsyg.2021.725525

Jiang, X. (2021). Women in STEM: Ability, preference, and value. *Labour Economics*, *70*, 101991.

Kirschner, P. A., & Lai, K. W. (2007). Online communities of practice in education. *Technology, Pedagogy and Education*, *16*(2), 127-131. https://doi.org/10.1016/j.labeco.2021.101991

Kolb, D. A. (2014). *Experiential learning: Experience as the source of learning and development*. FT press.

Kolb, D. A., Rubin, I. M., & McIntyre, J. M. (1984). *Organizational psychology: Readings on human behavior in organizations*. Englewood Cliffs, NJ: Prentice-Hall.

Kreber, C. (2006). Developing the scholarship of teaching through transformative learning. *Journal of Scholarship of Teaching and Learning*, *6*(1), 88-109.

Kreber, C. (2013). The transformative potential of the scholarship of teaching. *Teaching and Learning Inquiry*, *1*(1), 5-18. https://doi.org/10.20343/teachlearninqu.1.1.5

Lawrence-Lightfoot, S. (2005). Reflections on portraiture: A dialogue between art and science. *Qualitative Inquiry, 11*(1), 3–15. https://doi.org/10.1177/1077800404270955

Lawrence-Lightfoot, S., & Davis, J. H. (1997). *The art and science of portraiture*. Jossey-Bass.

Lee, S. Y. (2021). Rethinking teacher agency: Cybernetics, action research, and the process-oriented rationality. *Journal of Curriculum Studies*, *53*(6), 821-840. https://doi.org/10.1080/00220272.2020.1858451

Lesser, E. L., & Storck, J. (2001). Communities of practice and organizational performance. *IBM systems journal, 40*(4), 831-841. https://doi.org/10.1147/sj.404.0831

Liao, C. (2016). From interdisciplinary to transdisciplinary: An arts-integrated approach to STEAM education. *Art Education*, *69*(6), 44-49. https://doi.org/10.1080/00043125.2016.1224873

Liao, X., Luo, H., Xiao, Y., Ma, L., Li, J., & Zhu, M. (2022). Learning patterns in STEAM education: A comparison of three learner profiles. *Education Sciences*, *12*(9), 614. https://doi.org/10.3390/educsci12090614

McDonald, G., Le, H., Higgins, J., & Podmore, V. (2005). Artifacts, tools, and classrooms. *Mind, Culture, and Activity*, *12*(2), 113-127. https://doi.org/10.1207/s15327884mca1202_3

Montgomery, B. L. (2020). Academic leadership: Gatekeeping or groundskeeping?. *The Journal of Values-Based Leadership*, *13*(2), 16. https://doi.org/10.22543/0733.132.1316

Murray, J. (2006). Cybernetic circularity in teaching and learning. *International Journal of Teaching and Learning in Higher Education*, *18*(3), 215-221.

Nishioka, H. (2016). Analysing language development in a collaborative digital storytelling project: Sociocultural perspectives. *System*, *62*, 39-52. https://doi.org/10.1016/j.system.2016.07.001

Nizzolino, S., & Canals, A. (2021). Social network sites as community building tools in educational networking. In *E-Collaboration Technologies and Strategies for Competitive Advantage Amid Challenging Times* (pp. 76-143). IGI Global. https://doi.org/10.4018/978-1-7998-7764-6.ch004

Oguz, F., Marsh, C. V., & Landis, C. (2010). Collaboration through communities of practice in the digital age. In *Technological Convergence and Social Networks in Information Management: Second International Symposium on Information Management in a Changing World, IMCW 2010, Ankara, Turkey, September 22-24, 2010. Proceedings 2* (pp. 18-30). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-16032-5_3

Ole, F. C. B., & Gallos, M. R. (2023). Effects of feedback loop model on teachers' attitudes, self-efficacy and classroom practices towards formative assessment. *International Journal of Research in Education and Science*, *9*(1), 55-75. https://doi.org/10.46328/ijres.3006

Owusu-Agyeman, Y. (2021). Transformational leadership and innovation in higher education: A participative process approach. *International Journal of Leadership in Education*, *24*(5), 694-716. https://doi.org/10.1080/13603124.2019.1623919

Polizzi, S. J., Zhu, Y., Reid, J. W., Ofem, B., Salisbury, S., Beeth, M., ... & Rushton, G. T. (2021). Science and mathematics teacher communities of practice: social influences on discipline-based identity and self-efficacy beliefs. *International Journal of STEM Education, 8*, 1-18. https://doi.org/10.1186/s40594-021-00275-2

Prosser, M. (2008). The scholarship of teaching and learning: What is it? A personal view. *International Journal for the Scholarship of Teaching and Learning*, *2*(2), 2. https://doi.org/10.20429/ijsotl.2008.020202

Quigley, C., Trauth-Nare, A., & Beeman-Cadwallader, N. (2015). The viability of portraiture for science education research: Learning from portraits of two science classrooms. *International Journal of Qualitative Studies in Education*, *28*(1), 21-4 https://doi.org/10.1080/09518398.2013.847507

Rikoon, S., Finn, B., Jackson, T., & Inglese, P. (2018). Crosscutting literature on STEAM ecosystems, expectancy value theory, and social emotional learning: A metadata synthesis. *ETS Research Report Series*, *2018*(1), 1-15. https://doi.org/10.1002/ets2.12223

Riverin, S., & Stacey, E. (2008). Sustaining an online community of practice: A case study. *International Journal of E-Learning & Distance Education*, *22*(2). 43-58.

Scott, B., Shurville, S., Maclean, P., & Cong, C. (2007). Cybernetic principles for learning design. *Kybernetes*, *36*(9/10), 1497-1514. https://doi.org/10.1108/k.2007.06736iad.022

Shank, M. J. (2006). Teacher storytelling: A means for creating and learning within a collaborative space. *Teaching and Teacher education*, *22*(6), 711-721.

Skouge, J. R., & Rao, K. (2009). Digital storytelling in teacher education: Creating transformations through narrative. *Educational Perspectives*, *42*, 54-60. https://doi.org/10.1016/j.tsc.2020.100760

Smyth, P., & Carless, D. (2021). Theorising how teachers manage the use of exemplars: Towards mediated learning from exemplars. *Assessment & Evaluation in Higher Education*, *46*(3), 393-406. https://doi.org/10.1080/02602938.2020.1781785

Steele, A., & Ashworth, E. L. (2018). Emotionality and STEAM integrations in teacher education. *Journal of Teaching and Learning*, *11*(2), 11-25. https://doi.org/10.22329/JTL.V11I2.5058

Stoilescu, D. (2008). Modalities of using learning objects for intelligent agents in learning. *Interdisciplinary Journal of E-Learning and Learning Objects, 4*(1), 49-64.

Tasdemir, C., & Gazo, R. (2020). Integrating sustainability into higher education curriculum through a transdisciplinary perspective. *Journal of Cleaner Production*, *265*, 121759.

Tilak, S. (2023). Cybernetics, education, and psychology: Discovering potentials (yet) unearthed. *Cybernetics and Human Knowing*, *30*(1-2). https://doi.org/10.3390/su11030767

Tilak, S., & Glassman, M. (2022). Gordon Pask's second-order cybernetics and Lev Vygotsky's cultural historical theory: Understanding the role of the Internet in developing human thinking. *Theory & Psychology*, *32*(6), 888-914. https://doi.org/10.1177/09593543221123281

To, J., & Carless, D. (2016). Making productive use of exemplars: Peer discussion and teacher guidance for positive transfer of strategies. *Journal of Further and Higher Education*, *40*(6), 746-764. https://doi.org/10.1080/0309877X.2015.1014317

Trigwell, K. (2013). Evidence of the impact of scholarship of teaching and learning purposes. *Teaching and Learning Inquiry*, *1*(1), 95-105. https://doi.org/10.2979/teachlearninqu.1.1.95

Von Glasersfeld, E. (2019). Cybernetics, experience, and the concept of self. In *A Cybernetic Approach To The Assessment Of Children* (pp. 67-113). Routledge.

Vygotsky, L. S. (1978). *Mind in society*. Cambridge, MA: Harvard University Press.

Author Information

Christopher Dignam
Governors State University 1 University Pkwy
University Park, Illinois 60484
United States
Contact e-mail: *cdignam@govst.edu*
ORCID iD: https://orcid.org/0009-0007-3185-4825