Journal of STEM Teacher Education

Volume 56 | Issue 2 Article 5

November 2021

Community of Practice in Integrated STEM Education: A Systematic Literature Review

Jung Han
Purdue University, han336@purdue.edu

Todd R. Kelley
Purdue University, trkelley@purdue.edu

Nathan Mentzer
Purdue University, nmentzer@purdue.edu

J. Geoff Knowles
Bryan College, jknowles3910@bryan.edu

Follow this and additional works at: https://ir.library.illinoisstate.edu/jste

Part of the Education Commons

Recommended Citation

Han, Jung; Kelley, Todd R.; Mentzer, Nathan; and Knowles, J. Geoff (2021) "Community of Practice in Integrated STEM Education: A Systematic Literature Review," *Journal of STEM Teacher Education*: Vol. 56 : Iss. 2 , Article 5.
Available at: https://ir.library.illinoisstate.edu/jste/vol56/iss2/5

This Article is brought to you for free and open access by ISU ReD: Research and eData. It has been accepted for inclusion in Journal of STEM Teacher Education by an authorized editor of ISU ReD: Research and eData. For more information, please contact ISUReD@ilstu.edu.

Journal of STEM Teacher Education
2021, Vol. 56, No. 2, 62-80.

Community of Practice in Integrated STEM Education: A Systematic Literature Review

Jung Han
Purdue University

Todd R. Kelley
Purdue University

Nathan Mentzer
Purdue University

J. Geoff Knowles
Ivy Tech Community College

ABSTRACT

The efforts to integrate science, technology, engineering, and mathematics (STEM) in K-12 education have been increasing to help student learning and enhance 21st-century skills. The integrated STEM approach not only has pedagogical effects but also helps students prepare for STEM-related careers (ITEEA, 2020; NRC, 2012). Integrated STEM education is grounded in authentic, situated, and contextual learning, where Community of Practice plays a critical role. However, although educators and researchers have advocated Community of Practice as an important concept for learning, empirical research on Community of Practice within the integrated STEM context is limited. Additionally, how integrated STEM Communities of Practice are unique or not compared to other Communities of Practice and how these integrated STEM Communities of Practice function in the integrated STEM context have not specifically been researched yet. Therefore, the authors reviewed empirical studies focusing on Community of Practice in the integrated STEM context to identify the unique features of integrated STEM Community of Practice and its impacts on integrated STEM education. The results show the cross-disciplinary and interdisciplinary nature of the integrated STEM Community of Practice and suggest that building partnerships within and across Communities of Practice is critical in integrated STEM education. This review will help teachers and educators, especially of secondary education, understand the integrated STEM Community of Practice and guide them to establish Communities of Practice with experts and community partners to advance teachers' knowledge and skills and self-efficacies in teaching integrated STEM.

Keywords: Community of Practice, integrated STEM education, systematic literature review, situated learning, socially shared learning, K-12 education

Communities of Practice are "groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly" (Wenger, 2011, p.1). The concept of Community of Practice is related to socially shared practice, apprenticeship, and situated learning theory (Lave, 1991; Wenger, 2011), which indicates that learners can construct knowledge and metacognitive abilities through situated learning and socially shared practices (Brown et al., 1989; Collins et al., 1991; Lajoie et al., 2001; Levine & Marcus, 2010).

Although Community of Practice has been advocated among educators and researchers, research on Community of Practice in an integrated STEM context is limited. Therefore, the authors reviewed empirical studies focusing on the Community of Practice especially in the integrated STEM context in hopes to identify: 1) the unique features of the integrated STEM Community of Practice compared to other Communities of Practice, 2) its impacts on integrated STEM education, and 3) the ways integrated STEM Communities of Practice have been infused into the integrated STEM context.

The theoretical framework for this study was AUTHORS' (2016) *A conceptual framework for integrated STEM education*. In the framework, Community of Practice was the core concept as a facilitator for a successful implementation of integrated STEM curriculum. Within the framework, the current systematic literature review further investigated Communities of Practice in an integrated STEM context, where not only students but also teachers, researchers, STEM experts, and other community partners can be the members as learners as well as mentors. We hope that the findings will help educators and policymakers understand integrated STEM Communities of Practice and guide them to create real-life STEM contexts by establishing Communities of Practice with STEM experts and local community partners, where teachers can enhance knowledge, skills, and self-efficacies in teaching integrated STEM (AUTHORS, 2016).

Research Questions

This review was guided by the following research questions:

1) What is Integrated STEM Community of Practice?
2) What are the impacts of Community of Practice on integrated STEM education?

Literature Review

Integrated STEM Education

The contemporary STEM education movement demands science, technology, engineering, and mathematics (STEM) to be taught not in silos but in an integrative way (National Council of Teachers of Mathematics [NCTM], 2000; National Research Council [NRC], 2009, 2011, 2012; Wang et al., 2011). Integrated STEM requires curriculum integration across disciplines to teach different STEM domains simultaneously and engage students in a meaningful context (Moore & Smith, 2014; Radloff & Guzey, 2016; Sanders, 2009; Wang et al., 2011). According to Kelly and Knowles (2016), integrated STEM education can be defined as "the approach to teaching the STEM content of two or more STEM domains, bound by STEM practices within an authentic context for the purpose of connecting these subjects to enhance student learning" (Kelley & Knowles, 2016, p. 3).

This integrated STEM education has the potential to increase students' interest in STEM learning and problem-solving abilities. Dugger (2010) posited that "Integration of science, technology, engineering, and mathematics into a new cross-disciplinary subject in schools… offers students a chance to make sense of the integrated world we live in rather than learning fragmented bits and pieces of knowledge and practices about it" (p. 2). However, teachers face difficulties in

https://ir.library.illinoisstate.edu/jste/vol56/iss2/5

integrated STEM implementation as they lack professional knowledge to integrate STEM disciplines appropriately and establish a balance among content areas (Dare et al., 2018; Kertil & Gurel, 2016; Ntemngwa & Oliver, 2018). Moreover, finding quality materials and instructional strategies to integrate engineering and science practices is another challenge for many teachers (Guzey et al., 2016; Kelley & Knowles, 2016). To overcome the challenges, teachers need opportunities to engage in professional development, where they can build STEM knowledge, confidence, and practices necessary for this approach (Kelley & Knowles, 2016). In an integrated STEM professional development, teachers can practice collaborative teaching and develop a strong knowledge base to make connections across the disciplines (Ejiwale, 2013; Kertil & Gurel, 2016; Thibaut et al., 2018; Kelley et al., 2020).

Situated Learning

Kelley and Knowles (2016) noted that “most content in STEM can be grounded within the situated cognition theory” (p. 4). In the situated cognition theory, knowledge transfer occurs when students are exposed to authentic, coherent, meaningful, and purposeful activities (Brown et al., 1989).

In science education, the real-world applications are critical in promoting scientific inquiry, which cannot be achieved solely by the knowledge transmission from the teacher to students (National Research Council, 1996). Specifically, problem-based learning enables learners to engage in a real-life context, where they can apply conceptual knowledge to a new, continued situation (Brown et al., 1989; Lajoie et al., 2001). When students are provided with real-life problems, their scientific reasonings are enhanced while defining the problem, developing the hypothesis, collecting and analyzing data, developing and testing the solution, and evaluating their solution and problem-solving processes. The Standards for Technological and Engineering Literacy (STEL) also require students to “experience a process similar to what scientists, technologists, and engineers often engage in when approaching a real-world problem” through participating in making and doing practices (ITEEA, 2020, p.72).

The integrated STEM approach aims to find relationships between different STEM subjects and provide a relevant context for learning the contents (Kelley & Knowles, 2016). In their framework for integrated STEM education, Kelley and Knowles (2016) remarked about integrated STEM situated learning with engineering design as a critical factor like the following:

> Often when learning is grounded within a situated context, learning is authentic and relevant, therefore representative of an experience found in actual STEM practice. When considering integrating STEM content, engineering design can become the situated context and the platform for STEM learning” (Kelley & Knowles, 2016, p.4).

Community of Practice

Situated learning, Community of Learners, and Community of Practice are all connected within the cognitive theory. Using a pulley metaphor, Kelley and Knowles (2016) posited that situated learning in integrated STEM (load) can be lifted by Communities of Practice.

“The idea of a community of learners is based on the premise that learning occurs as people participate in shared endeavors with others, with all playing active but often asymmetrical roles in sociocultural activity” (Rogoff, 1994, p.209). Similarly, cognitive apprenticeship promotes social interactions in knowledge construction by exposing learners to a collaborative learning environment, where learners can observe, practice, and scaffold knowledge (Brown et al., 1989; Collins et al., 1991; Lajoie et al., 2001). The term *cognitive apprenticeship* supports context-dependent situated learning and emphasizes "learning in a domain by enabling students to acquire, develop, and use cognitive tools in authentic domain activity" (Brown et al., 1989, p.39).

On the other hand, Community of Practice is a term created to refer to the "community that acts as a living curriculum for the apprentice" (Wenger, 2011, p. 4). In a Community of Practice, people share expertise and passion for joint attention, and both novices and experienced practitioners can facilitate learning while observing, discussing, and actively engaging in shared practices (Levine & Marcus, 2010).

> A Community of Practice is a collection of people who engage on an ongoing basis in some common endeavor. Communities of Practice emerge in response to common interest or position and play an important role in forming their members' participation in, and orientation to, the world around them. Therefore, it provides an accountable link between the individual, the group, and place in the broader social order (Eckert, 2006, p.1).

In education, both teachers and learners are recommended to participate in shared practices in a Community of Practice as sociology of learning is an important element that should be considered for successful teaching (Collins et al., 1991). According to Kelley and Knowles (2016), integrated STEM education can be an ideal context to create a Community of Practice for teachers and students. In particular, the members of a Community of Practice in integrated STEM contexts often cross boundaries between the disciplines.

> The teaching and learning of a school subject discipline can be regarded as a Community of Practice whose core members are the subject's teachers and students. Participation and reification are the daily activities inside and outside the classrooms. An overarching STEM pedagogy deals with more than one Community of Practice (Science, Technology, Engineering, Mathematics), thus forming a bigger Community of Practice, and some members of these communities have multiple memberships. A primary task to develop a dynamic STEM pedagogy is to study how the Communities of Practice interact with and cross each other's boundaries (Leung, 2020, p.3).

In summary, increasing teacher awareness towards integrated STEM and their self-efficacy in teaching STEM through a Community of Practice is critical in integrated STEM education (Kelley et al., 2020; Knowles, 2017; Nadelson & Seifert, 2017; Nadelson et al., 2012; Yoon et al., 2012). By increasing teacher self-efficacy, teachers' comfort level and motivation to teach STEM content will also increase (Nadelson et al., 2012).

Method

For the systematic review, online databases Educational Resources Information Centre (ERIC) and Google Scholar were used. The search string used was: "Integrated STEM education" AND "Community of Practice".

A total of 648 journal articles, theses, dissertations, and conference proceedings were queried in the first search from the databases.

Table 1

https://ir.library.illinoisstate.edu/jste/vol56/iss2/5

Search Terms and Initial Limiters

Search Terms	Databases	Limiters
Integrated STEM Education Community of Practice	ERIC Google Scholar	Scholarly articles, conference proceedings, dissertations, and theses Published in 2016-2020

In the second step, many articles were removed following the inclusion and exclusion criteria (Bartholomew & Yoshikawa, 2018) (Table 2). Next, abstract screening was done, and conceptual and theoretical articles and review articles were removed, and only empirical articles were left. Lastly, articles irrelevant to the topic, *Community of Practice in Integrated STEM Education*, were removed through the full-text screening.

A total of 10 final pertinent articles remained at the end. Table 2 demonstrates the inclusion and exclusion criteria, and Figure 1 displays the screening process.

Table 2
Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Peer-reviewed	Published in other languages
Full-text available from the database	Review articles, Conceptual and theoretical articles
Published in English	Content is irrelevant of the topic, *Community of Practice in Integrated STEM Education*.
K-12 education	
Empirical papers (Abstract screening)	

The review followed the basic steps, which include organizing the studies, analysis within studies, and analysis across studies (Miles & Huberman, 1994; Petticrew & Roberts, 2003). All articles were carefully reviewed first, during which many themes emerged. The reviewers established codes from emerging themes, and each article was coded for further analysis. While establishing the codes, the reviewers considered Thibaut et al.'s (2018) nine categories of instructional practices, which were identified from a systematic review of 23 articles, and Margot and Kettler's (2019) pre-established codes that were developed for their systematic literature review (see Table 3).

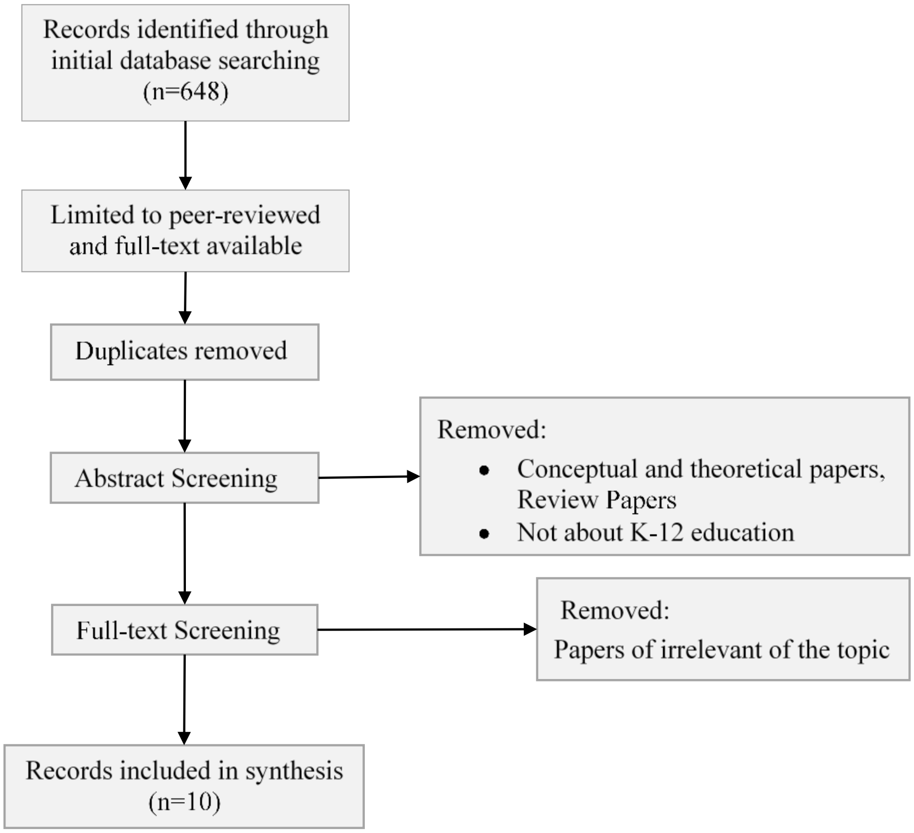

Figure 1. Flowchart for Screening Process. Modified from "The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration," by A. Liberati et al., 2009, Copyright 2009 by the Elsevier Inc.

Table 3
Codes for the Current Systematic Review

Thibaut et al. (2018)' nine categories of instructional practices	Margot and Kettler's (2019) four pre-established codes with refined sub-codes	**Established codes for the current systematic review**
STEM content integration	Teachers	Content integration
Focus on problems	Professional development	Design-based leaning
Inquiry	Prior experiences with STEM	Inquiry-based learning
Design	Working in collaborative teams	Project-based learning
Teamwork	Time (not enough)	Problem-based learning (Authentic real-world problem)
Student-centered	Knowledge of STEM disciplines	
Hands-on	Teachers' value of STEM education	Situated learning
Assessment	District	21st Century skills
21st Century skills	Support System	Community of Practice
	Assessments	

https://ir.library.illinoisstate.edu/jste/vol56/iss2/5

	Structural issues	Collaboration
	Students	Community engagement
	Student struggles	Professional development
	Enjoyment of STEM	
	Student concerns	
	Curriculum	
	Cross-curricular integration	
	Application activities	
	Curriculum materials	
	STEM pedagogy	

Result

This section systematically reviews the articles with the following research questions: 1) What is Integrated STEM Community of Practice? and 2) What are the impacts of Community of Practice on integrated STEM education?

All articles were purposefully selected from experimental studies about integrated STEM education. Authentic contexts and diverse Communities of Practice were identified from all studies.

Table 4 displays a brief overview of the articles and demonstrates authentic contexts and Communities of Practice identified from the studies. Table 5 summarizes all the articles and provides more specific information about the studies.

Table 4
Overview of the Articles

Authors	Country	Participants (n)	Community of Practice	Authentic Context
Burrows et al., 2018	USA	Middle school female students	Girl Scout participants, leaders, parents, university faculty, graduate students, and others	Informal educational setting (Girl Scout)
Holmlund et al., 2018	USA	STEM/ non-STEM teachers, administrators, STEM professional development providers	Teachers, administrators, STEM professionals, parents, district administrators	Traditional middle schools, a STEM-focused school, and state-wide STEM. Professional development
Jho et al., 2016	South Korea	Teachers from STEAM schools	STEAM teachers	Two STEAM specialized high school communities

				Online professional development
Kier & Khalil, 2018	USA	Two STEM teachers	Teachers, engineers, and university STEM teacher educators	Collaborative learning with professionals using digital platforms (students) Online professional development (teachers)
McCollough et al., 2016	USA	Pre- and in-service mathematics and science teachers	Pre- and in-service teachers, university faculties, scientists	Authentic situated professional development
Yuenyong, 2019	Thailand	STEM teachers	Teachers, professional, school administrators	Authentic professional development across the nation
AUTHORS, 2020	USA	STEM teachers	Teachers, university faculties, local industry partners	Authentic professional development
Leung, 2019	USA	Seventh grade mathematics teachers and students	Mathematics education researchers and teachers	Tool-based Mathematics learning in a science laboratory
Livstrom et al., 2019	USA	Survey participants (teachers, administrators, and curriculum specialists engaged in Montessori middle school science)	Teachers, Local community	Alternative formal education setting (Montessori middle School)
Lotter et al., 2020	USA	Rural secondary teachers	Teachers, Local community	Rural secondary schools Authentic professional development in a rural area

Table 5
Summary of the Articles

Title	Integrated STEM: Focus on Informal Education and Community Collaboration through Engineering (Burrows et al., 2018)
Abstract	Students experienced open-ended complex integrated STEM project (water quality river project) in an informal, authentic educational setting (i.e., Girl scout). Researchers as leaders and community partners formed a Community of Practice for student learning.
Data collection	Observational field notes, focus groups, artifacts collection

Results	Community members' knowledge and interests improved student learning in authentic, integrated STEM.
Discussion	Impact of participating in an informal, authentic STEM context and community engagement on student learning
Title	Making Sense of "STEM Education" in K-12 Contexts (Holmlund et al.,2018)
Abstract	The educators' conceptualizations of STEM education were analyzed from their concept maps and interviews after they experienced one of the three different learning contexts: two traditional middle schools, a STEM-focused school, and state-wide STEM.
Data collection	Concept maps, interviews
Results	Both context and role group contribute to STEM educators' conceptions.
Discussion	Conceptualizations of educators across roles and contexts will inform STEM education implementation in local and larger contexts.
Title	An Analysis of STEM/STEAM Teacher Education in Korea with a Case Study of Two Schools from a Community of Practice Perspective (Jho et al., 2016)
Abstract	Observation data from two STEAM (STEM + Art) schools were analyzed from a Community of Practice (CoP) perspective.
Data collection	Interviews, video records (lesson, observation), teacher documents
Results	The two communities showed a mutual relationship, mutual engagement, and shared repertoire.
Discussion	This study contributes to STEAM teacher education by providing practical implications from the successful implementation of STEAM teachers.
Title	Exploring How Digital Technologies Can Support Co-Construction of Equitable Curricular Resources in STEM (Kier & Khalil, 2018)
Abstract	The case study investigated how professional engineers supported STEM teachers in designing instructions for real-world problems and "contextualized career-related engineering design challenges" by using an online collaboration platform.
Data collection	Field notes, descriptive notes from online discussion, student and teacher artifacts (i.e., blog), etc.
Results	The Community of Practice (CoP) provided multiple sources for collaboration, and the teachers used digital technologies to communicate with professionals.
Discussion	The case study highlights the need for the co-construction of career-related STEM lesson plans instructions with engineers.

Title	Improving Secondary School Grades STEM Teacher Content Knowledge and Pedagogical Practices through a School-University Partnership (McCollough et al., 2016)
Abstract	To increase math and science teachers, authentic situated professional development was implemented through a University-School District partnership.
Data collection	Pre/post content tests for teachers, teacher survey, and standardized test for students
Results	The program showed positive impacts on teacher self-efficacy and outcome expectancy.
Discussion	The importance of engaging teachers in authentic practices in professional development with a Community of Practice
Title	Lesson Learned of Building Up Community of Practice for STEM Education in Thailand (Yuenyong, 2019)
Abstract	The paper discusses building Communities of Practice in integrated STEM education by addressing professional development implemented across Thailand.
Data collection	Informal conversations
Results	The professional development program established a big Community of Practice across the nation.
Discussion	Building partnership among teachers and schools administration for STEM education is critical for STEM education reform.
Title	Increasing High School Teachers Self-efficacy for Integrated STEM Instruction Through a Collaborative Community of Practice (AUTHORS, 2020)
Abstract	STEM teachers implemented integrated STEM lessons they developed during professional development and benefitted from a Community of Practice.
Data collection	Pre/post survey of teacher self-efficacy
Results	STEM teachers increased self-efficacy after professional development and implementing integrated STEM lessons in their classrooms.
Discussion	How to establish Communities of Practice for STEM teachers incorporating industry partners and university faculties need to be further researched.
Title	Exploring STEM Pedagogy in the Mathematics Classroom: a Tool-Based Experiment Lesson on Estimation (Leung, 2019)

https://ir.library.illinoisstate.edu/jste/vol56/iss2/5

Abstract	Boundary crossing within the STEM context was explored through a project developed by researchers and teachers, in which inquiry-based learning and mathematical modeling were integrated.
Data collection	Classroom observation field notes, teacher and student interviews, video record of lessons, student-produced materials, and audio recordings of the Community of Practice meetings
Results	The integration of inquiry-based learning and mathematical modeling was evident in the student work.
Discussion	Boundary crossing between disciplines needs to be further explored in the STEM education context.
Title	Integrated STEM in Practice: Learning from Montessori Philosophies and Practices (Livstrom et al., 2019)
Abstract	A survey was conducted to investigate how Adolescent Montessori science programs are implemented in an interdisciplinary way.
Data collection	Surveys
Results	Adolescent Montessori education program is well situated and happens in authentic, meaningful ways in Communities of Practice.
Discussion	Integrated STEM situations that happen naturally like Montessori need to receive attention for educational reform in STEM.
Title	Rural Teacher Leadership in Science and Mathematics (Lotter et al., 2020)
Abstract	Rural secondary science and mathematics teacher leadership was investigated during a three-year professional development program to identify the relationship between teacher leadership and student learning.
Data collection	Interviews
Results	Teachers gained new content knowledge through professional development, which enhanced their leadership and benefitted their students and other teachers in districts.
Discussion	Connections between teachers and local communities and building Communities of Practice are critical for teacher leadership and student learning.

Integrated STEM Community of Practice

Cross-disciplinary Community of Practice, community engagement, collaboration, and professional development emerged as common themes that describe integrated STEM Community of Practice. The uniqueness of the integrated STEM Community of Practice based on these themes will be addressed in this section.

Cross-disciplinary Community of Practice. From the systematic review, the *Cross-disciplinary Community of Practice* (Livstrom et al., 2019, p. 197) was identified as the most noticeable feature of the integrated STEM Community of Practice.

All integrated STEM Communities of Practice in the reviewed articles were identified as cross-disciplinary, and the members, including teachers and other professional members, shared knowledge and skills in a cross-disciplinary way. For example, in Communities of Practice, teachers plan, implement, and assess their instruction of subjects outside of their disciplines with support from peers and experts. Doing so relieve their anxieties about the new teaching strategies (Jho et al., 2016). Additionally, teachers' participation in the cross-disciplinary Community of Practice is expected to increase their self-efficacy in teaching STEM (AUTHORS, 2020; Livstrom et al., 2019; McCollough et al., 2016). In line with this, McCollough et al. (2016) remarked that "pre- and in-service teachers should be provided with extended experiences, frequent feedback and a strong, supportive professional learning community reinforced with structured mentoring to increase both knowledge and efficacy in STEM instruction" (p.57).

Interconnections between Communities of Practice were also identified in some studies. The articles show that community members often crossed communities and participated in other Communities of Practice to build successful conditions across communities in STEM education (Jho et al., 2016; Kier & Khalil, 2018). In Jho et al.'s (2016) study, two communities shared educational materials and project outcomes, and teachers could participate in the other community's professional development as instructors to share their knowledge and skills.

Finally, while discussing integrated STEM and the cross-disciplinary nature of Community of Practice in this context, Jho et al. (2016) and Leung (2019) emphasized the concept of *boundary crossing* (Jho et al., 2016; Leung, 2019). According to Leung (2019), "boundary pedagogy crossing the four disciplines… opens a new direction to interpret what STEM education is (Leung, p.1356).

Community Engagement. Community engagement is described as critical factor in integrated STEM education (Burrows et al., 2018; Holmlund et al., 2018; Jho et al., 2016; Yuenyong, 2019).

Integrated STEM projects often entail partnerships with STEM professionals, including researchers, university faculties, professional engineers, and scientists. Other community members such as school parents (Burrows et al., 2018) and local industry partners (AUTHORS 2020) also play an important role for the successful implementation of integrated STEM. All these members participate in Communities of Practice as instructors, mentors, or supporters. Stressing the impact of these Communities of Practice, Burrows et al. (2018) remarked that "hearing voices from the field allows a community to solve real-world problems, learn STEM concepts, and advance traditional K-12 learning together" (p.13).

Collaboration. Collaboration and sharing ideas are specific aspects of Community of Practice. The reviewed articles revealed that integrated STEM Community of Practice entails interdisciplinary connections, which involves collaboration necessarily. This interdisciplinary collaboration characterizes the cross-disciplinary Community of Practice, which is addressed above.

Specifically, Jho et al. (2016) proposed mutual engagement, joint enterprise, and shared repertoire as the three dimensions of Community of Practice and discussed that not just the members in a Community of Practice but members of different Communities of Practice also could

https://ir.library.illinoisstate.edu/jste/vol56/iss2/5

work together for the shared goals. Practically, some articles revealed collaborations between the Communities of Practice for the same problem-solving (Jho et al., 2016; Kier & Khalil, 2018).

Projects in authentic contexts and authentic situated real-world problems were also identified from all the reviewed articles. The members of the Community of Practice collectively contributed to the projects and collaborated for the successful implementation of integrated STEM. For example, in Holmlund et al.'s (2018) study, "Teachers collaborated across the school year to develop their own interdisciplinary, project-based curricula and used overarching themes to integrate the humanities and STEM disciplines" (p.5).

> Inherent in problem- and project-based learning are opportunities for student growth in twenty-first-century skills such as collaboration, critical thinking, creativity, accountability, persistence, and leadership (Buck Institute 2018; Partnership for 21st Century Skills 2013). These [integrated STEM] projects often encompass partnerships with STEM professionals and other community members who can help students make connections between school learning, problem-solving, and careers (Holmlund et al., 2018, p.3).

Therefore, building partnerships among teachers and school administration is critical for STEM educational reform (Holmlund et al., 2018; Yuenyong, 2019). For this purpose, it is imperative to provide multiple platforms for the members to communicate in. Some articles revealed that online communications in a Community of Practice expand the opportunities of collaboration (Kier & Khalil, 2018; Jho et al., 2016). According to Kier and Khalil (2018), "Within the Community of Practice, it was important for digital technologies that allow communication be flexible to allow for multiple modes of communication and different times depending on the preferences of individuals in the community" (p.117).

Professional Development. The Community of Practice approach is applied to integrated STEM education professional development to enhance teachers' interdisciplinary knowledge and instructional skills (Holmlund et al., 2018; Jho et al., 2016; Kelley et al., 2020; Kier & Khalil, 2018; McCollough et al., 2016; Yuenyong, 2019). In a Community of Practice in integrated STEM professional development, participants promote team collaboration, communication skills, and self-efficacy (Kelley et al., 2020; McCollough et al., 2016).

A mentoring system was also identified in the integrated STEM professional development (AUTHORS, 2020; Kier & Khalil, 2018; McCollough et al., 2016). During professional development, participant teachers received feedback from the community of STEM professionals while learning and practicing new skills (Holmlund et al., 2018; Kelley et al., 2020). "As teachers gained new content and pedagogical knowledge, they felt empowered to share this knowledge with others at their schools and districts" (Lotter et al., 2020, p.41).

Kelley et al. (2020) posited that quality integrated STEM professional development instruction should include "science inquiry and engineering design experiences, and collaborative approaches to situate learning within a Community of Practice, [where] novices and experts work together… to learn and connect STEM content and skills" (p.2).

Impact of Community of Practice on Student Learning in Integrated STEM

From the systematic review, Community of Practice was confirmed to be critical in integrated STEM education. As noted in the previous section, the integrated STEM Community of Practice is cross-disciplinary, where members from multiple disciplines collaborate for the shared goals.

In the reviewed articles, Communities of Practice exist in the form of communities of learners or communities of practitioners and novices, and both students and teachers benefit from participating in a Community of Practice together or separately (Leung, 2020). As noted earlier, collaboration, community engagement, and professional development emerged as key concepts for Community of Practice, and teachers benefit from this cross-disciplinary community of practice in the integrated STEM context. Community-driven learning and cross-disciplinary connections, which also characterize the integrated STEM Community of Practice, also contribute to students' STEM learning.

For the second research question, "What are the impacts of Community of Practice on integrated STEM education?" the reviewers confirmed that all aspects of situated learning in integrated STEM benefit from collective efforts of Community of Practice. Particularity, the empirical studies in the reviewed articles revealed important factors in integrated STEM education as content integration, design-based learning, inquiry-based learning, project-based learning, and authentic, real-world problem-based learning; all these factors were identified to benefit from integrated STEM Community of Practice.

Figure 2 depicts the summary of the systematic review of the ten articles, which shows that Community of Practice facilitates situated learning in integrated STEM.

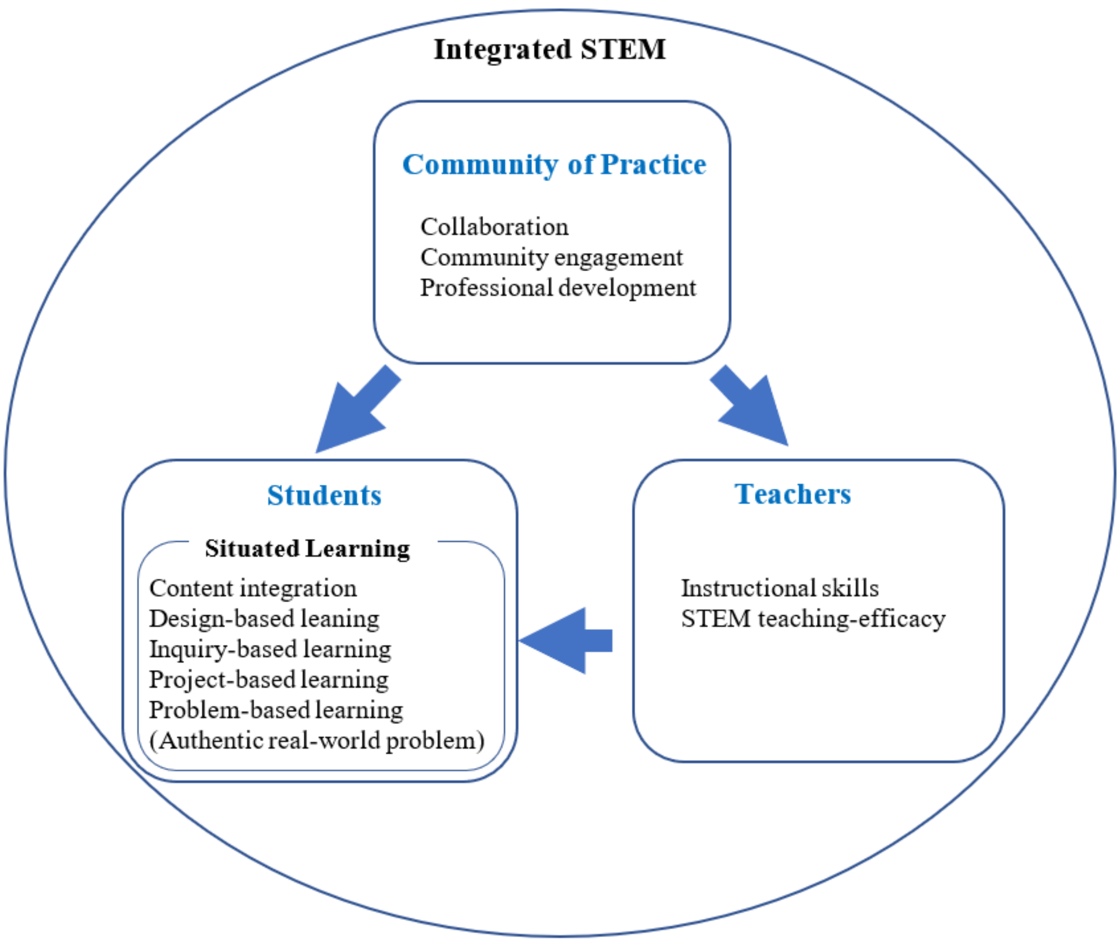

Figure 2. Community of Practice as a Facilitator for Situated Learning in Integrated STEM.

https://ir.library.illinoisstate.edu/jste/vol56/iss2/5

Conclusion

The aim of this study was to identify the unique features of the integrated STEM Community of Practice and its impacts on integrated STEM education. The results show the cross-disciplinary and interdisciplinary nature of the integrated STEM Community of Practice and suggest building partnerships within and across Communities of Practice for integrated STEM education.

In the reviewed articles, the authentic situation was described as the key element of integrated STEM and Community of Practice in this context. This result relates to previous literature that learning is situated and context-dependent and that knowledge transfer occurs when learners engage in authentic problem-solving activities embedded within a situation. As many researchers noted, socially-shared learning is supportive of a collaborative and situated learning environment (Brown et al., 1989; Collins et al., 1991; Lajoie et al., 2001), and this can be applied to an integrated STEM education context.

Additionally, professional development, communication among members, and community engagement were all identified as critical components of the integrated STEM Community of Practice. Regarding the impacts of Community of Practice on integrated STEM education, the articles show that the members of the integrated STEM Community of Practice contributed to student learning by enhancing teacher collaboration, instructional skills, and their self-efficacy in teaching STEM. Students also benefitted from participating in integrated STEM Community of Practice with teachers, STEM professionals, and other community members, who helped students "make connections between school learning, problem-solving, and careers" (Holmlund et al., 2018, p.3). This finding supports previous literature that the practice in a community is a dynamic process that involves everyone (Wenger, 2011).

From the systematic review, we suggest McCollough et al.'s (2016) key elements of the professional development model as fundamental factors to be considered for the integrated STEM education Community of Practice, which include: (1) a strong partnership between a school district and institution of higher education, (2) collaboration between educators and STEM professionals, pre-and in-service teachers, (3) a professional development and mentoring program designed around the school district's adopted course of study and the educational standards, (4) the integration of community resources, (5) a partnership with pre-service and in-service teachers and district administrators with STEM higher education faculty, (6) the development of teacher leaders, and (7) a comprehensive evaluation program (p. 50).

In summary, as we mentioned above, building partnership within and across the Communities of Practice is critical to advance student learning in integrated STEM. Therefore, we need to support teachers in establishing a Community of Practice where they can enhance STEM knowledge and skills and construct connectedness to the professional careers in authentic STEM contexts. We hope this review will help teachers and educators, especially of secondary education, understand the integrated STEM Community of Practice and guide them to establish Communities of Practice with experts and community partners to advance teachers' knowledge, skills, and self-efficacies in teaching integrated STEM.

References

Bartholomew, S. R., & Yoshikawa, E. (2018). A systematic review of research around Adaptive Comparative Judgment (ACJ) in K-16 education. *Council on Technology an Engineering Teacher Education: Research Monograph Series*.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational researcher*, *18*(1), 32-42. https://doi-org.ezproxy.lib.purdue.edu/10.3102/0013189X018001032

Burrows, A., Lockwood, M., Borowczak, M., Janak, E., & Barber, B. (2018). Integrated STEM: Focus on informal education and community collaboration through engineering. *Education Sciences*, *8*(1), 4. https://doi.org/10.3390/educsci8010004

Collins, A., Brown, J. S., & Holum, A. (1991). Cognitive apprenticeship: Making thinking visible. *American educator*, *15*(3), 6-11.

Dare, E. A., Ellis, J. A., & Roehrig, G. H. (2018). Understanding science teachers' implementations of integrated STEM curricular units through a phenomenological multiple case study. *International journal of STEM education*, *5*(1), 4. https://doi.org/10.1186/s40594-018-0101-z

Dugger, W. E. (2010, December). Evolution of STEM in the United States. In *the 6th Biennial International Conference on Technology Education Research at Gold Coast, Queensland, Australia*.

Eckert, P. (2006). Communities of Practice. *Encyclopedia of language and linguistics*, *2*(2006), 683-685.

Ejiwale, J. A. (2013). Barriers to successful implementation of STEM education. *Journal of Education and Learning*, 7(2), 63-74.

Guzey, S. S., Moore, T. J., & Harwell, M. (2016). Building up STEM: An analysis of teacher-developed engineering design-based STEM integration curricular materials. *Journal of Pre-College Engineering Education Research (J-PEER)*, *6*(1), 2. https://doi.org/10.7771/2157-9288.1129

Holmlund, T. D., Lesseig, K., & Slavit, D. (2018). Making sense of "STEM education" in K-12 contexts. *International journal of STEM education*, *5*(1), 32. https://doi-org.ezproxy.lib.purdue.edu/10.1186/s40594-018-0127-2

International Technology and Engineering Educators Association [ITEEA] (2020). *Standards for Technological and Engineering Literacy: Defining the Role of Technology and Engineering in STEM Education*, VA: Author.

Jho, H., Hong, O., & Song, J. (2016). An analysis of STEM/STEAM teacher education in Korea with a case study of two schools from a Community of Practice perspective. *Eurasia Journal of Mathematics, Science & Technology Education*, *12*(7). https://doi.org/10.12973/eurasia.2016.1538a

Kelley, T. R., and Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education, 3(1),* 11. https://doi-org.ezproxy.lib.purdue.edu/10.1186/s40594-016-0046-z

Kelley, T. R., Knowles, J. G., Holland, J. D., & Han, J. (2020). Increasing high school teachers self-efficacy for integrated STEM instruction through a collaborative Community of Practice. *International Journal of STEM Education*, *7*(1), 1-13. https://doi.org/10.1186/s40594-020-00211-w

Kertil, M., & Gurel, C. (2016). Mathematical modeling: A bridge to STEM education. *International Journal of Education in mathematics, science and Technology*, *4*(1), 44-55.

Kier, M. W., & Khalil, D. (2018). Exploring how digital technologies can support co-construction of equitable curricular resources in STEM. *International Journal of Education in Mathematics, Science and Technology*, *6*(2), 105-121.

https://ir.library.illinoisstate.edu/jste/vol56/iss2/5

Knowles, J. G. (2017). Impacts of professional development in integrated STEM education on teacher self-efficacy, outcome expectancy, and STEM career awareness. *ProQuest LLC*, ProQuest LLC, 2017.

Lajoie, S. P., Guerrera, C., Munsie, S. D., & Lavigne, N. C. (2001). Constructing knowledge in the context of BioWorld. *Instructional Science*, *29*(2), 155-186. https://doi-org.ezproxy.lib.purdue.edu/10.1023/A:1003996000775

Lave, J. (1991). *Situating learning in Communities of Practice.* In L. B. Resnick, J. M. Levine, & S. D. Teasley (Eds.), *Perspectives on socially shared cognition* (p. 63–82). American Psychological Association. https://doi.org/10.1037/10096-003

Leung, A. (2019). Exploring STEM pedagogy in the mathematics classroom: A tool-based experiment lesson on estimation. *International Journal of Science and Mathematics Education*, *17*(7), 1339-1358. https://doi-org.ezproxy.lib.purdue.edu/10.1007/s10763-018-9924-9

Leung, A. (2020). Boundary crossing pedagogy in STEM education. *International Journal of STEM Education*, *7*, 1-11. https://doi.org/10.1186/s40594-020-00212-9

Levine, T. H., & Marcus, A. S. (2010). How the structure and focus of teachers' collaborative activities facilitate and constrain teacher learning. *Teaching and Teacher Education, 26*(3), 389–398. https://doi.org/10.1016/j.tate.2009.03.001

Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P., ... & Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *Journal of clinical epidemiology*, *62*(10), e1-e34. https://doi.org/10.1016/j.jclinepi.2009.06.006

Livstrom, I. C., Szostkowski, A. H., & Roehrig, G. H. (2019). Integrated STEM in practice: Learning from Montessori philosophies and practices. *School Science and Mathematics*, *119*(4), 190-202. https://doi.org/10.1111/ssm.12331

Lotter, C., Yow, J. A., Lee, M., Zeis, J. G., & Irvin, M. J. (2020). Rural teacher leadership in science and mathematics. *School Science and Mathematics*, *120*(1), 29-44. https://doi.org/10.1111/ssm.12383

Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: A systematic literature review. *International Journal of STEM Education*, *6*(1), 2. https://doi.org/10.1186/s40594-018-0151-2

McCollough, C., Jeffery, T., Moore, K., & Champion, J. (2016). Improving middle grades STEM teacher content knowledge and pedagogical practices through a school-university partnership. *School-University Partnerships, 9*(2), 50-59.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. sage.

Moore, T. J., & Smith, K. A. (2014). Advancing the state of the art of STEM integration. *Journal of STEM Education: Innovations and Research*, *15*(1), 5.

Nadelson, L, Seifert, A., Moll, A., & Coats, B. (2012). i-STEM summer institute: An integrated Approach to Teacher Professional Development in STEM. *Journal of STEM Education, 13*(2), 69-83.

Nadelson, L. S., & Seifert, A. L. (2017). Integrated STEM defined: Contexts, challenges, and the future. *International Journal of Science Education 41*(10), 1387-1407. https://doi-org.ezproxy.lib.purdue.edu/10.1080/00220671.2017.1289775

National Council of Teachers of Mathematics (2000). Executive summary. In Principles and standards for school mathematics. Retrieved from http://www.nctm.org/uploadedFiles/Math_Standards/12752_exec _pssm.pdf

National Research Council [NRC]. (2009). *Engineering in K-12 education: Understanding the status and improving the prospects*. National Academies Press.

National Research Council [NRC]. (2011). *Successful K-12 STEM education: Identifying effective approaches in science, technology, engineering, and mathematics*. Washington: National Academies Press.

National Research Council. (1996). *National science education standards*. National Academies Press.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC : National Academies Press.

Ntemngwa, C. & Oliver, J.S. (2018). The implementation of integrated science technology, engineering and mathematics (STEM) instruction using robotics in the middle school science classroom. *International Journal of Education in Mathematics, Science and Technology (IJEMST), 6*(1), 12-40.

Petticrew, M., & Roberts, H. (2003). Evidence, hierarchies, and typologies: horses for courses. *Journal of Epidemiology & Community Health*, *57*(7), 527-529. http://dx.doi.org/10.1136/jech.57.7.527

Radloff, J., & Guzey, S. (2016). Investigating preservice STEM teacher conceptions of STEM education. *Journal of Science Education and Technology*, *25*(5), 759-774. https://doi-org.ezproxy.lib.purdue.edu/10.1007/s10956-016-9633-5

Rogoff, B. (1994). Developing understanding of the idea of communities of learners. *Mind, Culture, and Activity, 1*(4), 209–229.

Sanders, M. E. (2009). Stem, stem education, stemmania. Technology Teacher, 68(4), p.20-26

Thibaut, L., Knipprath, H., Dehaene, W., & Depaepe, F. (2018). The influence of teachers' attitudes and school context on instructional practices in integrated STEM education. *Teaching and Teacher Education*, *71*, 190-205. https://doi.org/10.1016/j.tate.2017.12.014

Wang, H. H., Moore, T. J., Roehrig, G. H., & Park, M. S. (2011). STEM integration: Teacher perceptions and practice. *Journal of Pre-College Engineering Education Research (J-PEER)*, *1*(2), 2. https://doi.org/10.5703/1288284314636

Wenger, E. (2011). Communities of Practice: A brief introduction. Retrieved from: https://scholarsbank.uoregon.edu/xmlui/bitstream/handle/1794/11736/A%20brief%20introduction%20to%20CoP.pdf?sequence=1&isAllowed=y

Yoon, S., Evans, M., Strobel, J. (2012). Development of the teaching engineering self-efficacy scale (TESS) for K–12 teachers. In *Proceeding of the American Society of Engineering Education (ASEE) Annual Conference and Exposition*. San Antonio, TX: ASEE.

Yuenyong, C. (2019, March). Lesson learned of building up Community of Practice for STEM education in Thailand. In *AIP Conference Proceedings* (Vol. 2081, No. 1, p. 020002). AIP Publishing LLC.

Authors

Jung Han
Ph.D. Candidate
Purdue University, Technology Leadership and Innovation
Email: han336@purdue.edu

Todd R. Kelley
Associate Professor

https://ir.library.illinoisstate.edu/jste/vol56/iss2/5

Purdue University, Technology Leadership and Innovation
Email: trkelley@purdue.edu

Nathan Mentzer
Associate Professor
Purdue University, Purdue Polytechnic Institute/College of Education
Email: nmentzer@purdue.edu

J. Geoff Knowles
Associate Professor
Bryan College, Department of Engineering
Email: jknowles3910@bryan.edu