STEM Leader Excellence: A Modified Delphi Study of Critical Skills, Competencies, and Qualities

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Abstract

With the push by government and business leaders for greater emphasis on STEM education at all grade levels, STEM leaders (i.e., educational leadership and teacher leaders) are challenged to pioneer integrative praxes that prepare students for success in a scientifically and technologically driven society. Additionally, these STEM leaders must transverse the barriers of developing transformative educational experiences that involve diverse stakeholders. This study utilized a modified Delphi technique to investigate what STEM leader skills, competencies, and qualities are identified as critical by STEM professionals within integrative STEM education. Findings are presented for the following seven themes: mission and culture, equity and social responsibility, infrastructure and programming, curriculum and instruction, professional growth, evaluation and assessment, and extended learning. These findings may inform the development of courses and programs that prepare or provide professional development for STEM leaders.

Keywords: Educational leadership; integrative STEM education; modified Delphi study; STEM leaders; teacher leaders

Integrative science, technology, engineering, and mathematics (I-STEM) education provides direction for teaching, leading, and learning practices related to students' abilities to identify, think critically about, and propose solutions to real-world problems. However, many educators are unfamiliar with the conceptualization and praxis of I-STEM curricula (Havice, Havice, Waugaman, & Walker, 2018; Herro & Quigley, 2017). School program leaders cultivating an I-STEM culture also encounter difficult challenges such as reorganizing STEM subjects for greater integration and fostering teacher's knowledge, confidence, and pedagogical practice (Shernoff, Sinha, Bressler, & Ginsburg, 2017; Nadelson & Seifert, 2017). Several states have developed STEM-certification systems that both recognize exemplars of I-STEM instruction and curriculum and promote the development of an I-STEM culture within schools. In particular, the Indiana Department of Education, Office of Workforce and STEM Alliances (2018) emphasizes the deployment of problem-, project-, and inquiry-based approaches to learning "while developing critical thinking skills and creating pathways to postsecondary readiness" (p. 6).

Although effective models of I-STEM education are still emerging (LaForce, Noble, King, Holt, & Century, 2014), positive outcomes in administrator and teacher praxis are evident. Professional development (PD) programs have been shown to significantly increase teacher and administrator self-efficacy in problem- and project-based learning (Havice et al., 2018), teacher collaborative efforts and educational technology use (Herro & Quigley, 2017), mathematics achievement (Burghardt, Hecht, Russo, Lauckhardt, & Hacker, 2010), and teacher involvement in community engagement (Havice, 2015). However, it is important to note that the catalysts for transformative paradigms and praxis are school administrators and teacher leaders. According to Myers and Berkowicz (2015), "no school district, or school for that matter, can prepare for a systemic change without a profound and abiding understanding among that system's leaders" (p. 58–59).

School leaders must be progressive and knowledgeable about I-STEM approaches to ensure that students are receiving quality curriculum and instruction that would prepare them to be well-informed, globally aware, and employable in a scientifically and technologically driven society (Daggett, 2010). Innovative leaders who aspire to make changes in the educational culture of the school must support and coach the faculty they lead (Day, Fleenor, Atwater, Sturm, & McKee, 2014).

Purpose

I-STEM education will require a significant shift in the philosophical framework and culture of schools (Myers & Berkowicz, 2015). Therefore, the skills, competencies, and qualities of leaders that underpin transformative I-STEM experiences should be identified to inform leader preparation and PD programs. The purpose of this study is to identify the critical facets and praxis needed for STEM leaders, both school and teacher leaders, that would more likely lead to program transformation with an I-STEM lens.

Methodology

Our effort to identify qualities of a STEM leader striving for excellence involved site visits to schools, semi-structured interviews with STEM leaders, and a three-round modified Delphi study. The Delphi technique enables a distributed panel of respondents—typically a purposeful sample of experts—to offer opinions and judgments anonymously and then compare their judgments against the aggregated results of all panelists during subsequent rounds. During the final round, the panel validates the study results. The Delphi technique has been used to identify retention barriers among female STEM professionals (Mlinar, 2015) and challenges encountered with teaching a STEM curriculum (Branscum, 2018).

Participants

A list of potential participants was compiled from school leaders (principals, directors, and STEM coordinators), state STEM leaders, and STEM experts (university faculty, professional development providers, and researchers). Twenty-four of the individuals invited to participate (around 70) granted informed consent and joined the panel. The majority of participants (62.5%) were principals or directors of schools, and 58.3% of participants were from Indiana (see Table 1).

Table 1
STEM Leaders Participating in the Delphi Study

	Elementary	Middle	High	Postsecondary	Indiana	Total
Principal or Director	4	3	3		9	10
Teacher Leader	2		1		2	3
State Administrator					2	2
	Science	T&E	Math	Other	Indiana	Total
STEM Professionals	1	2		2	1	5
University	1	2	1		0	4
Total					14	24

Round 1: Instrument and Results

School visitations and interviews were conducted with principals, directors, and evaluators of Indiana's STEM Certified Schools (Indiana Department of Education, Office of Workforce & STEM Alliances, 2018) to inform the development of the initial instrument. Analysis of field notes, interview transcripts, and the literature resulted in an extensive list of desirable qualities of a STEM leader. A systematic review of all qualities resulted in the emergence of seven distinct themes. Table 2 offers descriptions of the themes and the number of items within each theme.

Table 2

Structure for Three Delphi Questionnaires and the Number of Pre-established Items for Each Theme

Theme: The knowledge, skills, dispositions, or initiatives that enable a STEM leader to…	Round 1	Round 2	Round 3
Mission and Culture …develop a common vision of STEM education and garner commitment from faculty, students, and the community.	12	8	8
Equity and Social Responsibility … promote equity, fairness, and social responsibility as it relates to I-STEM.	8	10	5
Infrastructure and Programming …develop a school infrastructure (physical environment, scheduling, educational technology, and counseling) that supports I-STEM education.	20	6	9
Curriculum and Instruction …effectively facilitate the development of implementation of coherent systems of curriculum and instruction that promotes the I-STEM mission and goals of the school.	28	9	10
Extended Learning …effectively encourage and facilitate STEM teaching and learning beyond the regular school day.	10	1	2
Professional Growth … effectively facilitate professional growth as it relates to I-STEM.	26	10	9
Evaluation and Assessment … effectively facilitate student assessment and evaluation of curricular programs as it relates to I-STEM.	13	11	8
Total	117	55	51

In the Round 1 questionnaire, panelists considered each of the seven themes separately. After reviewing the description of the theme, panelists listed up to three critical qualities and then rated the pre-established items on a 5-point scale from *not at all important* (1) to *critically important* (5).

To analyze the open-ended responses from panelists (n = 432), two researchers independently analyzed each set of responses by first classifying each response as relevant or irrelevant to the current theme. For relevant items, the item was classified as either a unique quality, a variation of a preexisting rated item, or a generic quality of a school leader (e.g., persistent, passionate, and respectful). Interrater agreement ranged from 80% for Mission and Culture to 95% agreement for Professional Growth. A third researcher determined disagreements. After consolidating redundant items, the researchers identified 55 responses that added new qualities to the original list (see Table 3).

Of the 117 rated items, panelists rated 85% of items at 4.0 or higher, meaning that most qualities were deemed *important* (62 items) or *critically important* (37 items). Comparing participants by Indianans vs. non-Indianans and K–12 administrators vs. non-K–12 administrators using a Mann–Whitney U test yielded no statistically significant differences for items combined within the same theme.

Relative to themes, all of the Evaluation and Assessment items were deemed *important* or *critically important*; however, none of the items for Extended Learning were deemed *critically important*. This finding supports previous research on school leadership agreeing that “after-school programs are sound educationally but struggle to operate and sustain such programs” (Miller, 2005, p. 20). The challenges of implementing afterschool and summer-school programs include “recruitment, staffing, transportation, maintaining high quality programming, developing and maintaining robust community partnerships, and planning for their own long-term sustainability” (Mette, Biddle, & Fairman, 2016, p. a).

Table 3
Number and Examples of Panelists Responses to Open-Ended Items in Round 1

	Responses		
Theme	Total	Unique	Examples of unique responses
Mission & Culture	72	8	• understand change theory and implement strategies to foster an integrative STEM culture. • advocate for STEM educational opportunities at all grade levels.
Equity & Social Responsibility	69	10	• model cultural competence.

			• implement a transparent enrollment process that promotes equitable access for all.
Infrastructure & Programming	69	6	• foster the development of plans for educational technology support in STEM-based instruction. • effectively provide opportunities for support personnel (e.g., educational technologists, counselors, nurses….) to be a part of planning and implementing STEM initiatives.
Curriculum & Instruction	59	9	• include STEM and curriculum specialists in the development of curriculum and instruction. • create opportunities for students to develop 21st Century skills and subsequently increase their employability potential.
Extended Learning	55	1	• offer afterschool STEM activities and programs for families and community members.
Professional Growth	53	10	• enable STEM teams and teachers to visit STEM-certified schools. • initiate team-based professional learning, such as the Lesson Study approach and book study.
Evaluation & Assessment	55	11	• model how to assess students' STEM achievement integratively. • design and implement assessments that are differentiated based upon student needs.
Total	432	55	

Round 2: Analysis and Results

In the Round 2 questionnaire, panelists were asked to rate only the 55 unique items proposed by the panelists in Round 1. Results indicated that 12 of the items were rated *critically important* (mean of 4.5 or higher).

Round 3: Analysis and Results

During Round 3, 14 panelists completed the questionnaire by (a) validating the breadth of the *critically important* qualities of a STEM leader (mean of 4.5 to 5.0 on a 5-point scale) and (b) rerating those items from Round 1 and 2 that received a borderline score of 4.25 to 4.49 (51 items).

Panelists indicated 86% to 100% agreement for the breadth of the critically important qualities (mean of 4.5 or higher) of a STEM leader. Two categories—Evaluation and Assessment and Equity and Social Responsibility—received 86% agreement with two panelists noting eight minor exceptions (e.g., a rationale to elevate “safe learning/laboratory spaces”). None of the means for borderline items rose to the critical threshold of 4.5 of 5. As indicated in Tables 4–9, panelists achieved consensus as to the critical qualities of I-STEM leaders.

Findings, Discussion, and Implications

A modified Delphi technique was used to identify the critical qualities of a STEM leader striving for excellence. As stated previously, the panel consisted of 24 STEM educational leaders in total. Although participation waned during the three rounds of surveys, a consensus arose among the panel. In this section, findings are organized by theme.

Mission and Culture

Results indicated that an I-STEM leader embraces innovation, problem-solving, and evidence-based decision-making by employing collaborative leadership strategies (see Table 4) that engender value for an I-STEM curriculum and a mission that is focused upon the well-being and academic success of students. The collaborative leader embraces shared decision-making through team-based structures, in particular, a STEM leadership team comprised of a cross section of educational stakeholders. Collaborative leadership is based upon building relationships among people who recognize their interdependence, share a common goal, and share responsibilities. Facilitating a collaborative vision and learning culture is prominent among professional standards for school leaders (e.g., National Policy Board for Educational Administration, 2015). Collaborative leadership behaviors have been associated with higher trust levels among teachers, including shared visioning and collaborative decision-making (Owen, 2018).

Table 4
Critical Characteristics Related to Mission and Culture

Mission and Culture	Mean	*SD*	Round	*n*
1 promotes a culture of innovation, inquiry, problem-solving, and evidence-based decision-making.	4.83	0.38	2	18
2 impanels a STEM leadership team comprised of diverse stakeholders, e.g., faculty, students, parents, business and community leaders.	4.75	0.44	1	24
3 empowers a STEM leadership team to guide the development, implementation, and evaluation of I-STEM goals, expectations, programs, and initiatives.	4.67	0.56	1	24
4 articulates the value of I-STEM education to promote the well-being and academic success of students.	4.58	0.78	1	24
5 collaboratively develops an educational mission that promotes I-STEM curriculum and instruction.	4.54	0.59	1	24

Reducing the isolationism and independent decision-making that is pervasive within conventional schools is a challenge to creating a collaborative culture (Elbousty & Bratt, 2009). Overcoming these barriers is essential to the complex task of cultivating I-STEM curriculum because expertise is distributed among professionals. The facilitation practices of a collaborative leader often reflect the underlying tenets and processes of inquiry, cooperative learning, and design thinking. Thus, question posing, examining the relevance of evidence, considering possibilities, and experimentation with new ideas for I-STEM learning are commonly embedded facilitation practices.

Equity and Social Responsibility

Several qualities related to equity and social responsibility were rated as critical characteristics (see Table 5). Responses indicated that I-STEM curriculum and instruction should be provided for all populations of students, including students with disabilities, females, minorities, low socioeconomic students, and veterans. These paradigms were supported in school observations and interviews with successful I-STEM leaders who indicated that they were aware of inequities for marginalized groups and purposefully integrated multiple opportunities for students to engage in formal and informal STEM learning experiences.

Table 5
Critical Characteristics Related to Equity and Social Responsibility

Equity and Social Responsibility	Mean	*SD*	Round	*n*
1 ensures that all students have equitable access to I-STEM curriculum and instruction.	4.88	0.34	1	24
2 promotes equal access to STEM educational programming, e.g., participation in STEM academies, projects, competitive teams, and community-based learning experiences.	4.67	0.49	2	18
3 creates nonintimidating learning environments that are accessible to all students, including those with disabilities.	4.63	0.49	1	24
4 addresses female students, minority students, low socioeconomic students, and veterans.	4.58	0.50	1	24
5 Focuses on increasing participation of underrepresented students in STEM education.	4.50	0.59	1	24

Inclusivity in STEM education is complex because student needs are diverse, and barriers are often structural, cultural, and unconscious. Studies have shown that praxis of inclusivity leads to greater advocacy by teachers for student engagement in STEM opportunities (Frank & Hjalmarson, 2016) and increases the presence of marginalized groups in STEM positions (Huston, Cranfield, Forbes, & Leigh, 2019). The I-STEM leader striving for inclusive excellence has the acumen for identifying gaps in programming equity and social responsiveness and is compelled to implement solutions. Tanenbaum (2016) recommended increasing staff knowledge of equity issues, developing accessible measures of learning, engaging in the community, incorporating interdisciplinary approaches and STEM-themed play, and reducing historical biases through exposure to societal and cultural systems as key strategies for shaping inclusive school programs.

Curriculum and Instruction

The interconnected principles of science, technology, engineering, and mathematics and the “habits of mind” used by STEM professionals offer compelling content and authentic learning processes by which to plan curriculum and instruction within K–12 education. Although a variety of school models for STEM education are evident in the United States (LaForce et al., 2014), few large-scale research efforts compare different approaches to STEM integration (Honey, Pearson, & Schweingruber, 2014). Thus, the facilitation skills of STEM leaders are especially important in structuring a curriculum development team, mapping the curriculum, and assuring the adoption and skillful implementation of preferred I-STEM pedagogies and practices.

An effective I-STEM leader often initiates STEM program development by assembling a multidisciplinary curriculum planning team comprised of individuals who are committed to the ideal of improving STEM learning outcomes. Delphi panelists emphasized that the STEM curriculum team should be populated with teachers from science, mathematics, technology, engineering, and career and technical education, teachers across grade levels, curriculum integration specialists, and teachers of students with special needs and high abilities. Engaging student, parent, community, and business representatives was deemed less critical, but still important, by the panelists. However, broader representation on the team offers other advantages, such as fostering future community partnerships.

The Delphi panel emphasized that mapping the existing curriculum to identify common points for integration among the STEM content areas was the most critical step to achieving integrative curriculum. I-STEM leaders should be well versed in the processes and tools that support collaborative curriculum mapping, as well as the value of these processes to evaluate the coherence of the curriculum and promote shared understandings among teachers.

Consistent with K–12 standards from the *Standards for Technological Literacy* (International Technology Education Association, 2007) and the *Next Generation Science Standards* (NGSS Lead States, 2013) as well as engineering education in K–12 (e.g., Purzer, Strobel, & Cardella, 2014), the Delphi panel emphasized that learning experiences should engage students in the design and engineering of solutions to real-world problems (see Table 6). Related to problem-based learning (PBL) and project-based learning, design and engineering pedagogies (e.g., Donna, 2012) are learner-centered approaches that require students to grapple with problems by exercising their reasoning, creativity, and critical-thinking skills when proposing or testing a potential solution. Teachers facilitate this design process as students inquire into the nature of the problem, identify design goals and constraints, envision potential solutions, analyze computational and physical models, and predict potential trade-offs.

Delphi panelists emphasized that students should be given the opportunity to examine problems that exist within the local community, thereby enabling students to "explore uncertainties and build knowledge through experience." It was reasoned that locally situated problems help students understand how STEM content and practices are connected to each other and relate to their daily lives as well as commit to learning as a valuable lifelong process. However, planning locally situated, design-based learning experiences takes cognitive focus as well as more time and coordination of resources and will likely generate stress among teachers related to managing an open-ended learning experience (Shernoff et al., 2017). To address these challenges, I-STEM leaders should help teachers build their confidence and ability to implement PBL effectively, become knowledgeable about design and engineering pedagogical practices and principles (e.g., Crotty et al., 2017; Cunningham & Lachapelle, 2014), and dedicate time for collaborative curriculum and instructional development.

Table 6
Critical Characteristics Related to Achieving I-STEM Learning Outcomes

	Please rate how critical these are to achieving integrative STEM learning outcomes.	Mean	*SD*	Round	*n*
1	Ensure students engage in designing, engineering, making, testing, reflecting, and documenting.	4. 82	0.50	1	22
2	Continuously improve strategies that develop students' reasoning, problem-solving, creativity, and critical-thinking skills.	4.68	0.65	1	22
3	Focus learning upon real-world problems and projects.	4.64	0.58	1	22
4	Focus learning upon open-ended assignments that require students to reason using an integrated approach.	4.64	0.49	1	22
5	Encourages commitment to learning as a lifelong process.	4.61	0.50	2	18
6	Encourage creative thinking assignments which also engages in complex and difficult content.	4.59	0.59	1	22
7	Promote the use of technology and engineering processes for modeling and testing solutions.	4.59	0.59	1	22
8	Focuses on student-centric pedagogical approaches	4.56	0.62	2	18
9	Assure that part of the learning process comes from exploring uncertainties and constructing knowledge from experience.	4.55	0.60	1	22
10	Provide opportunities for students to pursue solutions to problems or needs within the local community.	4.50	0.80	1	22

Professional Development

"Effective educational leaders [have an obligation to] develop the professional capacity and practice of school personnel to promote each students' academic success and well-being" (National Policy Board for Educational

Administration, 2015, p. 14). To do so requires an assessment of staff learning needs, awareness of effective strategies that stimulate STEM learning, the selection or development of a professional learning program matched to that need, and resources to implement the impact of the initiative.

This study indicates that a critical characteristic of an I-STEM leader is to engage and sustain school staff in professional learning that enhances their STEM teaching practice by providing effective models of preferred I-STEM pedagogies, including inquiry, experimentation, design, and engineering (see Table 7). Panelists emphasized that time and resources were essential to exploring their own ideas for I-STEM approaches, but also valued mentoring and peer-to-peer coaching as part of their professional learning process.

Table 7
Critical Characteristics Related to Professional Development

	A STEM leader striving for excellence …	Mean	*SD*	Round	*n*
1	provides time and STEM-related professional development for educators to enhance their teaching practices.	4.71	0.46	1	21
2	encourages, supports, and challenges teachers to revise and explore their ideas for new I-STEM approaches.	4.67	0.58	1	21
3	provides mentoring or peer-to-peer coaching among staff members on I-STEM.	4.57	0.51	1	21
4	provides effective models in the instructional use of inquiry, experimentation, design, and engineering pedagogies.	4.57	0.75	1	21

School leaders have partnered with a plethora of PD providers, both nonprofit and for-profit, to enhance STEM teacher pedagogies and understanding of STEM content. Often, workshops and institutes mirror the learning process that their students would experience when encountering similar design challenges in school. Evidence regarding the impact of these PD programs on teacher practice is inconsistent. However, PD programs that were longer in scope and provided on-site or online support tended to show more positive impacts, especially regarding increasing one's teaching efficacy (e.g., Havice et al., 2018).

Job-embedded or site-embedded strategies should also be considered because they offer more continuous, personalized opportunities for professional learning within the teaching environment. Common strategies include peer observation, peer coaching (Staley, 2018), and integrated PD and curriculum design initiatives where STEM teachers learn together while collaboratively developing curricular units (McFadden & Roehrig, 2017). For job-embedded strategies, the STEM leader must bring to bear expertise as a collaborative facilitator, coach, and mentor as well as more extensive knowledge of STEM content and pedagogies. This expertise is invaluable in helping staff face their biases, overcome fears associated with using open-ended inquiry and design pedagogies, and build teaching efficacy.

Infrastructure and Programming

Developing spaces and facilitating time for meaningful I-STEM education planning and implementation involves "a reinvestment in usable instructional tools, including modern technology, to support transformative learning" (Basham, Israel, & Maynard, 2010, p. 18).

In this study, critical characteristics included creating school infrastructure and programming that provide accessible STEM learning and laboratory spaces that enabled inquiry, experimentation, and engineering to all students (see Table 8). Panelists indicated the need for current and relevant materials, resources, and technology in the learning spaces and time in the schedule that allows for authentic and collaborative learning to take place. Additionally, panelists emphasized the importance of shared teaching and planning times for educators as a part of an integrative, transdisciplinary approach to teaching STEM.

Table 8
Critical Characteristics Related to Infrastructure and Programming

	An effective STEM leader creates the school infrastructure and programming that...	Mean	*SD*	R	*n*
1	has STEM learning spaces accessible to all students.	4.79	0.41	1	24
2	has laboratory spaces equipped with technologies that enable inquiry, experimentation, and engineering.	4.63	0.49	1	24
3	provides appropriate and up-to-date materials, resources, and technology that facilitate integrative approaches to learning.	4.63	0.58	1	24
4	implements a schedule which allows time for authentic learning.	4.56	0.62	2	18
5	promotes transdisciplinary learning—wholistic understandings—through coplanning and coteaching.	4.56	0.70	2	18
6	has learning spaces that enable collaboration and project work among students.	4.54	0.59	1	24

The environment of I-STEM schools, classrooms, and programs should encourage collaboration, shared leadership, and knowledge sharing opportunities among teachers, students, and school leaders (Spillane, Lynch, & Ford, 2016). In a qualitative case study of an I-STEM model in one school district, Gardner and Tillotson (2019) found that school administrator support and encouragement regarding access to the Internet and technological devices for all students, schedules for teacher collaboration, and intentional pairing of teachers for coteaching promoted innovative experiences for students to learn, discover, and achieve in school.

The I-STEM leader must consider infrastructural school features that provide all students with access to educational spaces and current technologies for students to collaboratively explore engineering techniques and experimentation. To facilitate growth in I-STEM, makerspaces are becoming more popular and are utilized more in educational settings (Fasso & Knight, 2019). Within the school building, the development and use of makerspaces may be considered to facilitate exploration, experimentation, and teamwork to solve ill-defined problems.

Evaluation and Assessment

"A major aspect of expanding STEM education programs is providing compelling evidence of their effect" (Malyn-Smith, Na'im, Cedrone, & Supel, 2013, p. i); therefore, STEM leaders should be able to document evidence of I-STEM merit, deliver informed judgment, and communicate actionable feedback that would lead to measurable program outcomes. Delphi participants rated skills of conducting systematic evaluation and assessment as critical for an I-STEM leader while emphasizing that "providing actionable feedback to teachers" was the most critical (see Table 9).

STEM leaders should employ evidence from multiple sources to guide classroom- and school-level programming decisions. For example, performance-based assessments can convey to what extent the student is a good thinker and designer (Shively, Stith, & Rubenstein. 2018). Performance-based assessments were also identified by Delphi participants as a critical characteristic to promote inquiry, design-based, project-based, and problem-based learning. In their investigation of higher order proficiency through school-wide, performance-based assessment models, Ernst, Glennie, and Li (2017) found that "students demonstrated proficiency specific to brainstorming through drawing maps, exploration through collecting and tabulating data, and research and investigation" (p. 24). However, the researchers noted that proficiency separations amongst school sites were potentially impacted by school climate, individual teacher willingness and attitude to pursue performance-based assessments, and classroom practices.

Participants also rated the educational leadership's capabilities to align evaluation and assessment as critical for striving for excellence. In the state of

Indiana, the Indiana Department of Education (2019) has embedded alignment of academic standards within the STEM-certified school evaluation instrument. The expertise to assess the merit of I-STEM classroom and programming strategies are important qualities of a STEM leader because these outcomes are not traditionally measured in schools. Research has shown that STEM programs with purposeful STEM assessments positively increased STEM perceptions and career interest among diverse student populations (Lam, Doverspike, Zhao, Zhe, & Menzemer, 2008) and encouraged collaboration with stakeholders (Huffman, Lawrenz, Thomas, & Clarkson, 2006).

Table 9
Critical Characteristics Related to Evaluation and Assessment

	A STEM leader striving for excellence…	Mean	*SD*	Round	*n*
1	provides actionable feedback to teachers that enhances STEM instruction.	4.71	0.56	1	21
2	encourages the development and use of authentic performance assessment for design-based, project-based, and problem-based learning activities.	4.67	0.49	2	18
3	uses a variety of methods to measure students' understanding of and ability to implement an engineering design process.	4.67	0.49	2	18
4	Uses observation protocols to support high-quality STEM instruction.	4.64	0.58	1	21
5	gathers data from multiple sources to inform the evaluation of STEM programs.	4.62	0.50	1	21
6	develops a systematic process for evaluating STEM programs.	4.52	0.68	1	21
7	effectively evaluates the vertical alignment of I-STEM curriculum.	4.52	0.60	1	21
8	models how to provide actionable feedback to students that enhances their STEM learning outcomes.	4.52	0.68	1	21
9	assures that STEM evaluation and assessments are aligned with grade-level state standards.	4.50	0.62	2	18

Extended Learning

No characteristics in the Extended Learning category were rated as critical characteristics in this study. There are, however, compelling reasons for STEM leaders to form partnerships with community organizers and extend STEM learning opportunities beyond the school day. Heintz (2014) indicated that

STEM programs that take place outside of the school day promote partnerships with school and district staff, families, and community stakeholders, thus supporting the creation of internships, mentorships, and collaborative projects.

Researchers reported that STEM-focused extended learning opportunities increased students' interest and motivation in STEM, enhanced their perceptions of STEM subjects, and enhanced their understanding and practice in STEM fields (Chittum, Jones, Akalin, & Schram, 2017; Moreno, Tharp, Vogt, Newell, & Burnett, 2016). According to the Afterschool Alliance (2018), afterschool programs make "STEM more accessible, more interesting, and helps to build fluency" by engaging "students in hands-on, real-world projects," encouraging them to be entrepreneurial and innovative (p. 1). Afterschool robotics clubs and competitions have demonstrated several positive outcomes, such as increasing confidence in problem-solving and computer programming among students of underrepresented populations (Karp & Maloney, 2013).

In addition to afterschool programs, leaders should enable STEM-related learning experiences outside of the classroom, such as museum visits, science fairs, and field trips, and sponsor STEM-related student organizations or competitive teams, such as the Technology Student Association or Odyssey of the Mind. Alternatively, I-STEM leaders may encourage the use of simulations, media tools, and virtual environments that engage learners beyond the regular school day. STEM leaders should seek and foster partnerships with universities, 4-H, museums, and community centers for the development and delivery of services to underrepresented populations in STEM fields.

Limitations, Conclusions, and Recommendations

The reader should be alert to biases of the panel and researchers who reside at the same institution. The Delphi panel was purposefully populated with STEM education experts and school leaders whose schools had successfully achieved Indiana STEM certification. Thus, the results are likely biased toward the Indiana STEM certification criteria.

I-STEM education initiatives strive to prepare students as STEM-capable citizens in a scientifically and technologically driven world. Six themes were identified as critical for I-STEM leaders who strive for excellence, including mission and culture, curriculum and instruction, equity and social responsibility, infrastructure and programming, professional growth, and evaluation and assessment. The results are intended to inform the development and evaluation of programs that prepare school leaders who seek to advance I-STEM.

Recommendations

We recommend that institutions of higher education embed I-STEM leadership content in current courses or design and implement new leadership courses or programs to meet the needs of school and teacher leaders. Preservice and in-service building- and district-level administrators need to deepen their understanding of STEM education in order to promote innovation in I-STEM education, especially as it relates to supporting teachers' use of student-centered pedagogies, building their collaborative facilitation and STEM coaching skills, and fostering community partnerships.

Policymakers should fund and offer incentives to I-STEM leaders who implement evidence-based STEM practices, especially job-embedded PD programs, that empower teachers to develop, implement, and assess locally relevant I-STEM curriculum. To further diffuse I-STEM education, policymakers should support a centralized network by which I-STEM leaders could access STEM research, programming strategies, willing community partners, and PD opportunities.

Researchers should pursue the following questions: What are the conditions that best build I-STEM leaders' facilitation and coaching skills? What quality indicators are appropriate for evaluating I-STEM graduate and PD programs? Furthermore, the emergence of STEM certification programs indicates opportunities to examine and compare the impact of these programs upon certified and noncertified schools.

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