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Educators' Perceptions of Integrated STEM: A Phenomenological Study

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ABSTRACT

The study utilized a semistructured interview approach to identify phenomena that are related to integrated STEM education by addressing the question: What are the critical components of an integrated STEM definition and what critical factors are necessary for an integrated STEM definition's implementation? Thirteen expert practitioners were identified and interviewed. The interviews were transcribed and analyzed for content in three different ways: by person, by interview question, and across all interviews using exploratory data analysis methods. Ten identified phenomena were grouped into two classes: structural implementation phenomena and interpersonal implementation phenomena. The structural implementation phenomena were: subject integration, project-based learning, and design-based education; nontraditional assessment; STEM content; time; professional development; and outside support (from businesses and industry). The interpersonal implementation phenomena include: leadership; collaboration; willingness; authentic, relevant, and meaningful experiences for participants; and outside support (from people in business and industry). The analysis concluded that these phenomena could be considered both critical components and key implementation factors due to their interconnected nature. The data showed that the identified phenomena are necessary as part of an integrated STEM curriculum, which makes them critical components, and that the identified phenomena are critical to create and implement an integrated STEM setting, making them implementation factors as well. Implications for further research include: the possibility of looking at the interconnectedness of the phenomena, examining how each phenomenon contributes to integrated STEM, and measuring current STEM implementations to see if they incorporate the identified phenomena. Additionally, inclusion of an absent phenomenon could be researched to see if integrated STEM education is improved.

Keywords: Design-based education; Integrated STEM; Phenomenology; Project-based learning; Semistructured interviews; STEM education; Subject integration

Over the past decade, there have been numerous recommendations for changes in STEM education issued by the Obama administration (Change the Equation, n.d.; Handelsman & Smith, 2016; National Science and Technology Council, Committee on STEM Education, 2013; Sabochik, 2010), the National Research Council (2013, p. 38), and other interested groups (U.S. Department of Education, Office of Innovation and Improvement, 2016). One such group, the President's Council of Advisors on Science and Technology (2010), listed the main areas of need for the United

States. These identified needs are worthy of listing because they identify why STEM education is so critical. The,” (3) “cultivate future STEM experts” (p. 16),” and (4) “close the achievement and participation gap” (p. identified areas include: (1) “ensure a STEM-capable citizenry” (p. 15), (2) “build a STEM-proficient workforce. 17).

Reasons Driving Changes in STEM Education

A review of the literature identified four major reasons driving the changes in STEM education, the first of which is the pace of technological change. It has been noted by Peter Diamandis (2010) that “we are living in a world today that is global and exponential.” At no time in our past has information ever been generated at the pace of today. The video *The Information Age—We Are Living in Exponential Times* (Fisch, McLeod, & Brenman, 2013), based on research concerning “the progression of information technology,” states that “the amount of new technical information [being created] is doubling every 2 years.”

According to former Secretary of Education Richard Riley, the top 10 in-demand jobs now did not exist 5 years ago. We are currently preparing students for jobs that don’t yet exist using technologies that haven’t been invented in order to solve problems we don’t even know are problems yet. (Fisch, McLeod, & Brenman, 2013)

According to the U.S. Department of Commerce, “employment in STEM occupations grew much faster than employment in non-STEM occupations over the last decade (24.4 percent versus 4.0 percent, respectively), and STEM occupations are projected to grow by 8.9 percent from 2014 to 2024, compared to 6.4 percent growth for non-STEM occupations” (Noonan, 2017, p. 2).

The second reason driving change in STEM education is the comparison between scores of students in the United States and students in other countries, the results of which reveal that the United States lags behind many other nations in math and science. Results from the 2011 Trends in International Mathematics and Science Study (TIMSS) in mathematics revealed that fourth graders in the United States ranked 11th and eighth graders in the United States ranked ninth when compared to other nations (Mullis, Martin, Foy, & Arora, 2012). In science, fourth graders in the United States ranked seventh when compared to other nations, and eighth graders in the United States ranked 10th (Martin, Mullis, Foy, & Stanco, 2012).

A third reason driving change in STEM education is the difference in the way that Millennial-generation students are motivated, which is vastly different than any previous generation. According to researchers such as Howe and Strauss, Price, and Sweeney,

They [Millennials] are digital natives who . . . value experiential and exploratory learning . . . They are impatient, easily bored, and expect instant gratification. They believe (for better or worse) that they are expert multitaskers, and often switch between tasks such as homework, monitoring phone and Facebook feeds, and listening to music. They are team oriented and comfortable working in groups. (Rozaitis, 2013, para. 4)

Millennial students are a product of the information age and rapidly changing times, which have produced exponential growth in technology and innovation. This has resulted in a population who rapidly adapts to and masters new technology better than most previous generations.

The fourth reason driving change in STEM education is the growing economic imperative to keep up with the demand for STEM graduates. Unfortunately, the United States is not producing enough STEM graduates to fill the growing need for STEM-related jobs. According to the U.S.

Bureau of Labor Statistics, “there were nearly 8.6 million STEM jobs in May 2015, representing 6.2 percent of U.S. employment” (Fayer, Lacey, & Watson, 2017. p. 2). Meanwhile, “employment in STEM occupations is projected to increase 10.1% from” 2015 to 2025 compared with 6.5% growth for non-STEM occupations (Simmons, 2016, para. 3). According to Varas of the American Action Forum (2016), the United States will face a shortage of “1.1 million STEM workers in 2024” (p. 3). In *Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5*,

The National Academies *Gathering Storm* committee concluded that a primary driver of the future economy and concomitant creation of jobs will be *innovation*, largely derived from advances in science and engineering. While only four percent of the nation’s work force is composed of scientists and engineers, this group disproportionately creates jobs for the other 96 percent. (National Academy of Sciences, National Academy of Engineering, & Institute of Medicine, 2010, p. 2–3)

STEM careers have an advantage that would attract workers: They generally pay better than other jobs. In 2010, the Economics and Statistics Administration (Langdon, McKittrick, Beede, Khan, & Doms, 2011) found that “STEM workers command higher wages, earning 26 percent more than their non-STEM counterparts” (p. 1). Furthermore, “STEM degree holders enjoy higher earnings, regardless of whether they work in STEM or non-STEM occupations” (p. 1).

Rationale for the Study

Evidence in the literature suggests that integrated STEM has the potential to increase knowledge and conceptual learning (Honey, Pearson, & Schweingruber, 2014; Pfeiffer, Overstreet, & Park, 2010; Sherrod, Dwyer, & Narayan, 2009; Wilhelm & Walters, 2006). Because of the evidence supporting integrated STEM education, some educators have begun to develop conceptual frameworks to help implement integrated STEM approaches (e.g., Kelley & Knowles, 2016). Researchers have found that integrated STEM increases student interest, including minority student interest (e.g., R. Brown, Brown, Reardon, & Merrill, 2011; DeJarnette, 2012; Hayden, Ouyang, Scinski, Olszewski, & Bielefeldt, 2011; Katehi, Pearson, & Feder, 2009; Sahin, 2013). Despite the fact that research suggests that integrated STEM education can have a positive effect, one difficulty remains in that there are many different definitions of integrated STEM education (J. Brown, 2012; Merrill & Daugherty, 2009; Sanders, 2012; U.S. Department of Education, 2007). However, several research studies have found that integration of STEM content had a positive effect on student achievement and performance (e.g., Becker & Park 2011; Hurley, 2001; Scott, 2012).

Study Purpose and Conceptual Framework

In light of the above evidence in literature related to the benefits of integrated STEM education and the lack of consensus regarding what is integrated STEM education and how to implement integrated STEM education, the purpose of this study becomes relevant in today’s educational climate. The purpose of this study is twofold: (a) to identify the elements that STEM experts believe are the critical components of an integrated STEM education curriculum and (b) to identify factors, based on expert opinion, that suggest how best to implement an integrated STEM curriculum in a public high school. This study was designed to answer the following research questions.

1. What are the critical components that collectively define integrated STEM education?
2. What critical factors are necessary for implementing integrated STEM education programs?

Figure 1. Conceptual framework for the study.

A conceptual framework to focus the data analysis phase of the study was constructed using a review of the literature and the work of Kelley (2012) and Kelley and Knowles (2016). The conceptual framework for this study has three components. The first component consists of three pedagogical methods identified in the literature: project-based learning, design-based education, and subject integration (Kelley, 2012). The second component, integrated STEM education, is composed of the STEM curricular disciplines: science, technology, engineering, and mathematics. The third component is the curricular support structures found in schools and identified in the literature. The conceptual framework for this study is shown in Figure 1.

Method

The study utilized a phenomenological research design with semistructured interviews of expert STEM practitioners. The University of Nebraska at Omaha STEM Leadership Team identified experts in the field of STEM education based on their experience and expertise. It should be noted that all study participants have received numerous awards and honors related to their teaching of STEM and integrated STEM content. Multiple lists of possible participants were analyzed, and the most common or highly recommended individuals were solicited for interview. The initial group of experts were identified and contacted by the researcher, and then further experts were sought

out to fill in areas of expertise and to make the group as representative as possible. The interviews were conducted utilizing an interview protocol with the researchers following a script. During the interviews, the researchers took notes and developed further probing questions to deeply understand the participant's opinion regarding STEM education. These further probing questions were asked of participants and became data to consider during the data analysis process.

"Typical sample sizes for phenomenological studies range from 1 to 10 persons" (Starks & Trinidad, 2007, p. 1375). In a meta-analysis of phenomenological studies, Guetterman (2015) found that the sample size in education studies "ranged from 8 to 31" (p. 13). Some recommend a sample size "ranging in number from 5 to 25 (Polkinghorne, 1989)" (Creswell, 1998, p. 54), and Morse (1994) recommended a sample size of "approximately six participants" (p. 225). Taking into account these recommendations about sample size, the interview pool for the current study consisted of 13 expert STEM practitioners. Eight of the participants held a master's degree, and five held a doctoral degree. Nine of the participants were male, and four were female. Most participants (12 out of 13) had experience in K–12 classrooms within one of the STEM disciplines. Eight of the participants had their primary teaching experiences in high school settings, three had their primary teaching experiences in middle school settings, and one had their primary teaching experiences in the elementary setting.

The interviews were recorded and transcribed in their entirety. They were analyzed three different ways using Tukey's (1977) exploratory data analysis methods, which allowed data to be analyzed both qualitatively and quantitatively. The first analysis consisted of analysis by participant. In this analysis, the researchers reviewed the entire interview and identified key words, phrases, and ideas. This analysis was provided to the participant along with a complete interview transcript, and they could add, redact, or modify their responses. The first analysis was then turned into an executive summary of each interview. The second analysis was performed at the question level in which each interview question was looked at across all 13 interviews. The final analysis was across all interviews. In this analysis, the researchers removed all questions from the interview and used axial coding to look for themes in the interviews.

Themes were generated as the data were analyzed in each of the three different ways. When the identified themes began to surface in more than one of the analyses, the theme was identified as a theme of interest. However, to rise to the level of a phenomenon that is critical to integrated STEM education, the researchers required that at least 10 participants mentioned the phenomenon as important to integrated STEM. Initial indications from the interviews were that the identified phenomena were interconnected in such a way that if any of them were missing, integrated STEM education would be less than ideally realized.

Results

Two research questions were addressed by the study: (1) What are the critical components that collectively define integrated STEM education, and (2) what critical factors are necessary for implementing integrated STEM education programs? When the research questions were developed, the researchers anticipated that participants would mention tangible "things" that could be considered critical components of integrated STEM education. However, instead of citing "things" as critical components, participants spoke about intangible qualities like "willingness," methods like "project-based learning," needs like "leadership" or "outside expertise,"

or processes like “collaboration.” These intangible qualities are actually implementation factors for integrated STEM because the participants semantically spoke about them as if they were necessary to create integrated STEM education. The analysis of the participants’ responses led the researchers to conclude that the “critical components” of research question one and the “implementation factors” of research question two are in fact the same thing. Instead of stratifying them by the research questions, the data analysis indicated that the identified phenomena should be grouped into two distinct classes: structural implementation phenomena and interpersonal implementation phenomena. The structural implementation phenomena are related to structures or items that need to be in place to create and implement integrated STEM education. The interpersonal implementation phenomena are related to interpersonal skills that educators need to have or experience in order to create and implement integrated STEM. The phenomena identified in the data are as follows:

- Structural implementation phenomena
 - Subject integration, project-based learning, and design-based education
 - STEM content
 - Professional development
 - Time
 - Nontraditional assessment
- Interpersonal implementation phenomena
 - Collaboration
 - Willingness
 - Authentic, relevant, and meaningful experiences for educators and students
 - Leadership
 - Outside support (by business, industry, and people)

These phenomena are highly interconnected. When a participant mentioned one phenomenon, it was usually in the context of other phenomena. For instance, it was not uncommon for a participant to say something like, “Teachers must have time for and be willing to participate in professional development that provides experience with collaborative environments incorporating authentic real-world experiences.” This statement ties together five of the phenomena identified in the interviews. The fact that the identified phenomena are both critical components and implementation factors for integrated STEM education might be the reason that they are so highly interconnected. The analysis of the data shows that participants believe the following statements: (a) You must have collaboration as part of the learning process for students; therefore, (b) professional development for teachers must include collaboration because it replicates experiences similar to what will be asked of students. Based on the analysis of data and relationships identified via axial coding, the interconnected natures of the identified phenomena are illustrated in Figure 2.

Phenomenon 1: Subject Integration, Project-Based Learning, and Design-Based Education

This phenomenon was found to be related to other phenomena identified by the participants, including: assessment, professional development, willingness, and STEM content. This phenomenon surfaced in all the interviews. Twelve out of 13 participants specifically stated that integrated STEM education must have a project-based learning approach. The concept relating to the “subject of integration” for the STEM disciplines surfaced throughout all the interviews. All 13 participants also mentioned or implied the real-world nature of design-based education. Participants

Integrated STEM Phenomena Identified in Interviews

Figure 2. The interconnectedness of identified integrated STEM phenomena.

spoke to the need for teachers who are willing to try to incorporate these pedagogical methods into the classroom. The data indicated overwhelming evidence that assessments of integrated STEM need to include project-based learning and integrated STEM subjects through real-world applications. The participants believe that teachers' professional development must incorporate these phenomena to provide teachers with the necessary experience base to teach effectively in an integrated STEM environment.

Phenomenon 2: STEM Content

This phenomenon was related to the other identified phenomena, including: subject integration, project-based learning, and design-based education; professional development; and willingness. The importance of STEM content was evident throughout all facets of the interview. The analysis of the data shows that participants believe the following two statements. STEM content is the core education content, whereas subject integration, project-based learning, and design-based education serves as the delivery method, and nontraditional assessment is the measure of quality instruction. To teach STEM content effectively in an integrated setting, willing teachers need professional development in STEM content areas.

Phenomenon 3: Professional Development

This phenomenon was related to other phenomena identified in the synthesis of the transcripts, including: subject integration, project-based learning, and design-based education; authentic, relevant, and meaningful experiences; STEM content; collaboration; leadership; outside support; and willingness. The phenomenon of professional development was found in all the interviews. The analysis of the data shows that participants believe the following three ideas: (1) If integrated STEM is to be successful, the teachers of integrated STEM must be trained by having experiences that are integrated and collaborative in nature; (2) leadership in professional development must come from school leaders, business, and industry representatives; and (3) the teachers themselves to make the professional development as relevant as possible.

Phenomenon 4: Time

This phenomenon was related to other phenomena by the participants, including: collaboration, professional development, assessment, and authentic, relevant, and meaningful experiences. The phenomenon of time surfaced in some fashion in all the interviews, and 12 out of 13 participants specifically mentioned the need for time related to integrated STEM education. The analysis of the data shows that participants believe the following five statements. Time is needed for teachers to plan and collaborate. Time is needed for students and teachers to explore and think in integrated STEM environments. Time is needed to assess what students have learned and produced through the process. More time is needed to teach STEM in an integrated fashion than to teach the four subjects individually because of the time required to teach the relationships between the individual subjects. Integrated STEM will take time for both teachers and students in order to be successfully implemented.

Phenomenon 5: Nontraditional Assessment

This phenomenon was also related to other phenomena found in the analysis of the participants, including: subject integration, project-based learning, and design-based education; authentic, relevant, and meaningful experiences; time; and collaboration. The phenomenon of nontraditional assessment was found in all the interviews. The participants spoke about extended project-based assessments that were collaborative in nature in authentic real-world environments. The analysis of the data shows that participants believe the following two ideas. Due to the integrated nature of the content, the assessments must also be integrated to assess the relationships between the STEM components. Overwhelmingly, it was believed by the participants that a paper-and-pencil test would not properly assess integrated STEM, although this type of assessment might be appropriate for formative assessments. The assessments of integrated STEM learning need to be hands-on assessments in which students attempt to solve some problem that is presented in an interconnected set of topics relevant to students or real-world problems.

Phenomenon 6: Collaboration

This phenomenon was related to other phenomena found in the data, including: professional development, time, leadership, and willingness. The phenomenon related to the importance of collaboration was evident throughout the entire interview: 11 of 13 participants spoke about the importance of collaboration, team teaching, and cohorts as critical to integrated STEM education.

These activities (collaboration, team teaching, and cohorts) were all seen by the participants as collaborative in nature as such were grouped together under the collaboration phenomenon. The participants spoke about collaboration being a necessary part of student projects and assessments. They referenced collaboration between teachers as part of the instructional process and in professional development. The participants also discussed collaboration between schools, businesses and industry, and higher education. Participants viewed integrated STEM as being highly collaborative at all levels between all participants, which directly correlates to the previous phenomenon in that there needs to be time to collaborate for students and teachers. The analysis of the data shows that participants believe the following statement: Leadership from willing teachers and willing school leaders must be collaborative if integrated STEM is to become mainstream and be implemented successfully.

Phenomenon 7: Willingness

This phenomenon was related to other phenomena, including: collaboration; time; subject integration, project-based learning, and design-based education; and professional development. The phenomenon related to the willingness of teachers to participate in integrated STEM was evident throughout the entire interview. Ten of 13 participants spoke about the importance of willingness of teachers to participate as critical to integrated STEM education. From the data, it is readily apparent that for integrated STEM to be created and implemented, the involved parties must be willing to work, change, adapt, and learn.

Phenomenon 8: Authentic, Relevant, and Meaningful Experiences

This phenomenon was closely related to assessment, professional development, and outside support by people and businesses. Ten of 13 participants spoke in various ways about the importance of authentic, relevant, and meaningful experiences as being important to integrated STEM education. The participants felt that authentic, relevant, and meaningful experiences are critical for students in integrated STEM education and are critical for teachers to have experience with as part of professional development. The study participants felt that these types of experiences would motivate students and allow teachers to provide relevancy related to STEM content for students. The participants also stressed that outside support from businesses and industry in providing real-world experiences for students or teachers who can take that knowledge back to the classroom is important.

Phenomenon 9: Leadership

The study participants related this phenomenon to collaboration, professional development, and outside support by business, industry, and people, and the literature specifically mentions leadership by school leaders. Leadership was a focal point of all the participants. However, they see leadership related to the creation and implementation of integrated STEM as much more than just school leadership. Specifically, they spoke about leadership conceptually as shared leadership, which needs to come from teachers, school officials, students, outside experts, and community members alike. The analysis of the data shows that participants believe the following two statements. Leadership through professional development and collaborative activities is essential as well as leadership in how integrated STEM is created and implemented. Integrated STEM will

take many different parties working together headed by a group of people with a shared vision leading the effort.

Phenomenon 10: Outside Support by Business, Industry, and People

Outside support is a bridge between the structural and interpersonal phenomena because it had aspects of both that were found in the interviews. Regarding the structural implementation phenomena, this phenomenon was most closely related to professional development. Outside support was prevalent in the interviews: 10 out of 13 participants mentioned outside support in various ways. Primarily, participants discussed that outside support for integrated STEM can help provide training and professional development. The analysis of the data shows that participants believe the following ideas. Support can come from business and industry and can provide teachers with applications of STEM content to bring relevancy to the curriculum. This can happen by teachers going to the business in an internship-like experience or through business and industry experts leading professional development workshops for teachers. It was also mentioned that higher education needs to serve an important role in teachers' professional development by facilitating and leading collaborative efforts with business and industry. The participants believe that higher education needs to shift teacher preparation programs to be more hands-on, collaborative, and problem-based in nature for integrated STEM to be successful.

Regarding the interpersonal implementation phenomena, this phenomenon was related to leadership, collaboration, and authentic, relevant, and meaningful experiences by the participants. Outside support was prevalent in the interview: 10 of 13 participants mentioned outside support in various ways. The participants see outside support as necessary for providing relevant professional development. It was also stated that outside experts could come into the classroom and provide expertise related to authentic, real-world experiences for students as well as expertise that a teacher might lack related to specific STEM content.

Phenomenon 11: Nonconsensus

A unique final phenomenon that was identified during the analysis of the data was the phenomenon of nonconsensus. This phenomenon was not included in the list of phenomena that were directly drawn from the interviews because it was not explicitly stated by the participants. Instead, it was discovered by investigating the items on which the participants showed significant disagreement or no agreement whatsoever. A phenomenon related to nonconsensus is important because if the thirteen interview participants from the study were all in disagreement on an item, it is likely that other practitioners would have similar concerns and disagreement. According to the data, there are four major areas of nonconsensus that need to be addressed. Schools should be aware of these areas of nonconsensus when creating and implementing an integrated STEM curriculum because they could pose potential stumbling blocks that would need to be addressed. The primary areas of nonconsensus revealed during the analysis of the interviews were: (1) integrated STEM as an elective or core class, (2) certification requirements for integrated STEM, (3) integrated STEM relating to standardized testing, and (4) the cost of an integrated STEM program. These areas of nonconsensus can serve as points of discussion when a school begins the process of creating and implementing an integrated STEM curriculum. Consensus, or at least partial agreement, must be reached related to these areas for an integrated STEM program to be effective.

Additional Themes of Interest

In addition to the identified phenomena, there are several other implementation factors to consider. First, there was consensus among the participants that staffing changes were not necessary in order to implement integrated STEM education; however, according to the methods adhered to in the study, not enough participants said this to reach the level of a phenomenon. Second, there was consensus among the participants who believed that training or retraining of people, or augmenting the staff with some specialty personnel will be necessary to create integrated STEM. However, as with theme one, a majority but not enough respondents said this to reach the level of a phenomenon. Third, the participants spoke to and indicated that staff did not need to be fired and different staff hired to create and implement integrated STEM. Rather, they felt that through the use of leadership; outside support; professional development; collaboration; authentic, relevant, and meaningful experiences; and willingness, any teacher could become a competent integrated STEM teacher, particularly current STEM discipline teachers. These factors are the very phenomena that were identified as key implementation factors. Therefore, this theme reinforces the importance of the phenomena that were identified from the interviews.

Discussion

The study identified 10 phenomena that the participants feel are essential to create and implement integrated STEM education programs and discovered one additional phenomenon, nonconsensus. The 10 identified phenomena are critical components of integrated STEM because if any one of them were missing, integrated STEM as envisioned by the participants would be greatly diminished. The 10 identified phenomena are also implementation factors because integrated STEM cannot be implemented without the identified phenomena being present. The interconnectedness of the phenomena and the fact that the data showed that they are all necessary for integrated STEM as well as being necessary for the implementation of integrated STEM made the identified phenomena both critical components and implementation factors.

The findings in this study suggest that the identified phenomena work in concert to produce something that is more than the sum of its parts. Because the phenomena are large concepts, each phenomenon can be combined with other phenomena as part of the instructional process. This is an important consideration for measuring the performance of existing integrated STEM programs or when attempting to begin a new program. An evaluator must be aware of the interconnectedness of the parts of the integrated STEM process in order to determine overall program effectiveness. If a program is deficient, is it because of a lack of or weakness in a particular component? The interconnected nature of the phenomenon also makes implementation of integrated STEM difficult. Educational practitioners must be well versed in and comfortable with a number of different strategies, methods, learning styles, and teaching methods in order to implement integrated STEM. The interconnectedness of the phenomena identified in the study will require much planning and leadership to properly leverage all the connections.

A primary difference between the identified phenomena in the literature and the identified phenomena in this study was that the phenomena identified in the study were much more highly interconnected than the literature appears to indicate. In the literature, many of the identified phenomena were present. However, the reports and articles that identify what needs to be present in integrated STEM programs list phenomena but do not discuss how the cited phenomena

interconnect with each other. The literature tends to put forth large ideas and purports that by doing these things, one can create an integrated STEM curriculum. However, the results of this study suggest that there are many more variables in play that affect each other in an integrated STEM curriculum. Perhaps this is why the participants spoke about leadership from so many different perspectives. Integrated STEM will require leadership from all stakeholders in order to balance the interaction between the phenomena that make up integrated STEM creation and implementation.

As the literature states, there is much disagreement about what integrated STEM is and how it functions. This fact might make it impossible and perhaps inappropriate to have a definition of integrated STEM on which everyone can agree. With that being said, the participants desired a definition for integrated STEM education. Rather than creating a singular definition of integrated STEM, the authors propose the creation of an operational definition that can be utilized locally in order to build consensus about what a particular integrated STEM program will look like and accomplish. To that end, based on the results of this study, the following operational definition of integrated STEM education might serve as a place to begin discussions in local environments attempting to create and implement integrated STEM programs.

Integrated STEM education involves the purposeful integration of science, technology, engineering, and mathematics as well as other subject areas through project-based learning experiences that require the application of knowledge to solve authentic, real-world problems in collaborative environments for the benefit of students.

Implications for Future Research

The implications for future research are many. One area for future research is to further explore the interconnectedness of the phenomena identified in the interviews. Are all of the identified phenomena necessary for successful integrated STEM programs, or can some phenomena be left out? What is the bare minimum of the identified phenomena that are required for successful implementation of integrated STEM programs? Is a particular phenomenon more important than another? Understanding the answers to these questions will allow schools to focus critical resources where they will derive the best return.

A second area for future research would be to explore the value that each phenomenon specifically contributes to integrated STEM and to further identify the specific characteristics of the phenomenon. This would involve an in-depth examination of a single phenomenon using quantitative and qualitative methods to determine how a particular phenomenon relates to integrated STEM as well as specifically what that phenomenon represents. For instance, is one particular area of leadership important than another, or is one aspect of outside support more important than another? If an organization has limited resources, this type of research could help to optimize the impact of resources.

A third area for future research would be to analyze existing STEM implementation programs in the context of the identified phenomena to see if the phenomena identified here are present. This type of research study could serve as a gauge for the quality of a STEM education curriculum and suggest ways to improve STEM education by incorporating phenomena that were identified as important but might not be present.

A final area for future research would be to replicate this study in different educational environments, such as community and technical colleges, 4-year higher educational settings

, magnet secondary schools, and elementary settings in which STEM is incorporated into the curriculum. This would determine if the phenomena are universal across types and levels of educational settings or if there are variances that warrant further research.

Conclusion

The study utilized semistructured interviews of 13 recognized expert STEM educators to identify how to create and implement an integrated STEM program. Ten phenomena were identified as being essential to integrated STEM programs. These phenomena are highly interconnected, and the data show that the phenomena support and strengthen each other. Areas of nonconsensus were noted and must be considered if school systems are seeking to implement integrated STEM programs because areas of nonconsensus can pose obstacles that must be overcome. Even though a single definition of integrated STEM might never be possible or even appropriate, an operational definition of integrated STEM was presented as a starting point for local schools to use when beginning to create an integrated STEM program.

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