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STEAM (SCIENCE, TECHNOLOGY, ENGINEERING, ART, AND MATHEMATICS) EDUCATION AND TEACHERS' PEDAGOGICAL DISCONTENTMENT LEVELS

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Abstract

Literature focused on the emerging implementation of STEAM (Science, Technology, Engineering, Art, and Mathematics) education within K-12 education programs in the USA emphasizes the need for researchers to address the potential for disrupting the pedagogical contentment of teachers assigned to teach in STEAM disciplines who have no backgrounds in the fields represented by STEAM and/or who have no prior teaching experience in the areas of STEAM. Research objectives for the current study focused on examining the influence of intensive professional development on K-12 teachers' pedagogical discontentment levels relative

to the implementation of STEAM in all classrooms within a rural school district in the southeast region of the United States. Data sources included: (a) pre-post assessments of 93 teachers' pedagogical discontentment levels; (b) classroom observation data collected by external observers; and (c) teachers' perceptions of STEAM coaching. Data retrieved were analyzed using quantitative analyses. Study findings indicated teachers' pedagogical discontentment levels decreased over time. Future research must support teachers new to STEAM activities.

Keywords
K-12 STEAM education; Teachers' Pedagogical Discontentment; Coaching STEAM Teachers

1. Introduction

The emerging implementation of K-12 STEAM (Science, Technology, Engineering, Art, and Mathematics) education within the United States and globally has created concerns for educators and researchers relative to two major focus areas: (a) the influence of STEAM topics on classroom instruction within fully integrated STEAM K-12 classrooms (Taylor, 2015) and (b) the associated impact on teachers' perceived instructional confidence and competence levels (Mansfield, 2017; Meschede, Fiebranz, Moller, & Steffensky, 2017, Taylor, 2015). The trepidation or insecurity expressed by teachers who have no backgrounds in the fields represented by STEAM or who have no prior teaching experience in the areas of STEAM provides the rationale and purpose for examining teachers' pedagogical considerations (Mansfield, 2017). Elementary teachers with little or no preparation in STEAM coursework and secondary teachers who may be impacted by STEAM teaching assignments and/or collaborations with other teachers rather than teaching a single subject within STEAM content are faced with integrating STEAM content and activities in virtually all classrooms. Placing teachers in positions for teaching unfamiliar content may create discomfort within teachers and subsequently propel feelings of uneasiness or discontentment. Southerland et al. (2012) described teachers' pedagogical discontentment as "an affective state that occurs when a teacher recognizes a mismatch between her/his science teaching pedagogical goals and classroom practices" (p. 3). The potential for disrupting the pedagogical contentment levels of teachers with no backgrounds or experience in STEAM is a primary concern of educational researchers (Eger & Deerlin, 2015; Fishman, Penuel, Allen, Cheng, & Sabelli, 2013; Ge, Ifenthaler, & Spector, 2015; Maeda, 2012; Rieder, Knestis, & Malyn-Smith, 2016). A majority of teachers in the United States have identified problem-solving and critical thinking skills as the number one need

for teachers to include in instruction for all students (Center on Education Policy, 2016). Teachers must feel comfortable in teaching these STEAM skills and these skills are directly related to teachers' pedagogical contentment levels. Teacher discontentment may directly impact student receptivity to integrated STEAM learning.

Two research questions posited from the literature review served as the catalyst for the current study, i.e., RQ1: How does the immersion of K-12 teachers into a school district-wide STEAM program impact the pedagogical discontentment levels of the teachers? RQ2: What factors introduced into the implementation of a K-12 STEAM education initiative into a school district influence teachers' pedagogical discontentment?

2. Methodology

The methodology used in the research project included a one-group, pre-post quantitative research design of N=93 teachers who were selected as STEAM teachers (by application) for participating in a district wide integration of STEAM into all 30 schools within the district. Three specific types of measures were used within the study: (a) a quantitative pre-post assessment measure of STEAM teachers' pedagogical discontentment levels; (b) a classroom observation form used by trained external observers to assess classroom climates and activities; and (c) a mentor-mentee form the STEAM teachers completed to assess their individual experiences with their respective STEAM coaches. Each of these assessment instruments is presented relative to their individual purposes within the study.

The major instrument used for measuring pedagogical discontentment of the 93 teachers within the one-group quantitative pre-post assessment method for determining teachers' pedagogical discontentment mean score changes from pre to post assessment aligned with the research design and pertinent to RQ1 for the study was the *Science Teachers' Pedagogical Discontentment Scale or STPDS* (Southerland et al., 2016) slightly modified by the researchers replacing the word "science" with the word "STEAM". The *STPDS* (Southerland et al., 2016) is comprised of 21 items (statements) for teachers to rate using a 5-point Likert scale whereby the 93 designated

K-12 STEAM education teachers rated their perceived level of confidence with a rating of "1" as very little or no confidence and a rating of "5" as a high level of confidence. The following four items are examples of the type of content included in the *STPDS* (Southerland et al., 2016).

Item #6: *Using inquiry-based learning within all content areas.*

Item #8: *Assessing students' nature of STEAM understandings.*

Item #10: *Teaching STEAM to students from economically disadvantaged backgrounds.*

Item #12: *Having sufficient STEAM content knowledge to generate lessons.*

Teachers were pre-assessed at the beginning of the school year and post assessed at the end of their professional teaching year to determine possible changes in their levels of pedagogical discontentment scores. The instrument was used as a pre-assessment for all STEAM teachers prior to their annual 80 hours of STEAM professional development activities occurring from September to March each year and the post assessment was performed after the annual STEAM professional development activities were concluded in March. The pre and post assessments of the teachers also contained a demographic section for teachers. The study consisted of 93 teachers completing pre and post assessments during a two-year period, i.e., during the fall of 2015 and spring of 2016 and during the fall of 2016 and the spring of 2017. The same teachers participated in both years. The school district mandated the participation of the teachers in the STEAM professional development activities and assessments each year as part of their teaching contract obligations. Teachers were assigned and designated as STEAM teachers for the district with three teachers per each of the 18 elementary and five high schools and four teachers for each of the six middle schools for a total of 29 school sites and 93 STEAM teachers.

The second instrument utilized in the study was the classroom observation form whereby eight external observers were hired and trained by the researchers to consistently visit the 93 classrooms within the district over an eight-month period for the purpose of assessing the activities and environments of the classrooms of the STEAM teachers. Quantitative observations were performed by eight observers (doctoral students) trained by researchers to assess all STEAM classrooms according to four areas of focus: Creativity, Critical Thinking, Communication; and Collaboration. Each of the four areas were rated by observers on a scale from one to four using the following ratings: 1= Descriptive; 2= Emerging; 3= Developing; and 4= Accomplished. Observers visited STEAM classrooms for 30 minutes twice a week for 20 weeks each year collecting quantitative data related to the four areas of focus for a total of 1754 observations over two years. Although these data were not matched with specific STEAM teachers by name as per the requirement of the school district, the information gleaned from these data were aligned by school and grade level to provide a picture of the evolving pedagogical efforts of the STEAM teachers. These data were also used by researchers to

determine specific areas of discomfort and focused impact on classroom environments of the STEAM teachers providing information pertinent to RQ2. Classroom observation data provided a clear picture of the classroom climates, types of activities creating feelings of discomfort, and some evidence of the topics and focus areas impacting STEAM teachers' contentment levels as a group. School district protocol did not allow researchers to match individual classroom observation data to individual STEAM teachers because these data could be used for evaluating teacher performance and was not an allowable practice by the teachers' union regulations.

Researchers were also eager to discern the degree of impact of the STEAM coaches' influences on STEAM teachers' pedagogical discontentment levels. Ten STEAM coaching teachers were provided to the school district by an external partner company with the school district for assisting the STEAM teachers. One coach for every nine STEAM teachers was provided as a resource person. STEAM coaching teachers were trained instructors in STEAM fields but working for a private company focused on integrating STEAM into classrooms across the United States. The researchers were not provided information concerning the matching of coaches to teachers as per the district level protocol agreement. Instructional STEAM coaching teachers were assigned to the STEAM teachers each year as resource experts for STEAM content or instructional assistance in classrooms. STEAM coaches were available to teachers upon request with one STEAM coaching teachers for every nine STEAM teachers. STEAM teachers were asked by researchers to complete a mentor-mentee assessment instrument to determine the influence and impact of the STEAM coach on STEAM teachers' pedagogical discontentment levels. Although researchers were not allowed to pair specific STEAM coaches to STEAM teachers participating in the study, the overall influence of the coaching element relative to the STEAM teachers' pedagogical discontentment levels was a strong data acquisition consideration for the current study. The quantitative mentor-mentee instrument used in the study measured STEAM teachers' perceptions of their coaches as mentors and STEAM teachers' perceived impact of the role of the coaches within the STEAM coaching component of the overall STEAM program. STEAM teachers' perceptions of coaching provided information pertinent to RQ2.

Each of the three instruments used within the current quantitative study provided information relevant to specific areas of interest: (a) the use of the pre-post *STPDS* (Southerland et al., 2016) provided researchers with the change in pedagogical discontentment levels of STEAM teachers examined over a two-year time period; (b) the classroom observation form provided general

information concerning STEAM classrooms' activities and environments over a two-year time period of observations conducted by externally trained observers; and (c) the mentor-mentee instrument provided STEAM teachers' perceptions of the impact and use of STEAM coaches in assisting instruction. These three types of assessment instruments provide a strong portrayal of the STEAM teachers perceived instructional environments, the STEAM teachers' available resources, and the STEAM teachers' pedagogical discontentment levels over a two-year implementation period. Data retrieved from the three assessment sources contributed to the researchers' responses and analyses for answering the research questions posited for the study, i.e., RQ1: How does the immersion of K-12 teachers into a school district-wide STEAM program impact the pedagogical discontentment levels of the teachers? RQ2: What factors introduced into the implementation of a K-12 STEAM education initiative into a school district influence teachers' pedagogical discontentment levels? Descriptive and inferential analyses of quantitative data from the three sources were performed to provide empirical evidence for determining appropriate responses to the research questions posited in the study. Descriptive data analyses included frequency distributions of demographic information collected for describing the N= 93 STEAM teachers who participated in the study. Dependent t tests or paired t test analyses were performed for determining mean differences from the pre to post assessments of the STEAM teachers' responses to the *STPDS* (Southerland et al., 2016). Appropriate analyses for aligning with the assumptions for performing the paired samples t tests were conducted by researchers prior to the calculations of the dependent t test results to respond to RQ1. Descriptive information retrieved from the classroom observation forms were reported as frequency distributions for year one and year two of the study to provide empirical evidence of the STEAM classroom instructional atmospheres to assist researchers in responding to RQ2. STEAM teachers' perceptions of their STEAM coaches and activities were also examined using descriptive statistics analyses to respond to RQ2. Although the three types of assessments and their resulting analyses were not analytically connected by teacher identity as per the request of the school district and the protocol mandated by the teachers union for the study, the resulting findings are pertinent to the empirical assessment of STEAM teachers' pedagogical discontentment levels and by examining potential factors influencing teachers' pedagogical discontentment levels via observational data analyses to discern answers for RQ1 and RQ2.

3. Results and Discussion

Results of the data analyses are presented relative to the following four areas of discussion: (1) demographic information related to the N= 93 STEAM teachers who participated in the study; (2) results of the dependent t tests for determining mean differences in the pre and post assessments for assessing teachers' pre and post pedagogical discontentment levels for responding to RQ1; (3) descriptive frequencies of STEAM teachers' classroom observation data collected by external trained observers for responding to RQ2; and (4) descriptive statistics highlighting STEAM teachers' perceptions of their STEAM coaches' assistance as a resource

3.1 Demographic Results and Discussion.

Demographic information related to the N= 93 STEAM teachers who is presented in Table 1.

Table 1: *Frequency Distribution of N= 93 STEAM Teachers' Demographic Information*

Number of Years Teaching	f	%		Ages of STEAM Teachers	f	%
< 5 years	16	17%		< 25 years	4	4%
5 to 10 years	27	29%		25 to 35 years	27	29%
11 to 15 years	17	18%		36 to 46 years	33	36%
16- 20 years	19	20%		47 to 57 years	24	26%
>20 years	15	16%		>Age 57	4	4%
Missing data	0	0%		Missing data	1	1%
TOTAL	N= 93	100%		TOTAL	N= 93	100%
Gender of STEAM Teachers	f	%		Ethnicity of STEAM Teachers	f	%
Male	9	10%		Hispanic	1	1%
Female	84	90%		Native American	0	0%
Other	0	0%		Caucasian	87	94%
				African American	3	3%
				Asian	1	1%
				Other	1	1%
TOTAL	N=93	100%		TOTAL	N=93	100%
Highest Degree Held				Favorite Subjects Taught		
Bachelor's Degree	64	69%		Math/Sciences Technology	67	76%
Master's Degree or Higher	29	31%		Liberal Arts/Reading	26	24%
TOTAL	N=93	100%			N=93	100%

Results depicted in Table 1 provide an overview of the N= 93 STEAM teachers' demographic characteristics of age, gender, ethnicity, highest degree held, and associated number of years of teaching experience. Areas of competency depicted by teachers' reported favorite subjects (disciplines) to teach were categorized as (a) math/science and technology and (b) liberal arts and reading. The demographic representation of the N= 93 teachers is depicted as overwhelmingly white (94% Caucasian) and female (90%). Approximately one-third of the STEAM teachers hold masters' degrees or higher and more than half (54%) reported more than ten years in the teaching profession. The reported ages of the STEAM teachers included 96% of the STEAM teachers reporting ages 25 to over 60 indicating a small group (4%) of STEAM teachers under the age of 25 or teachers new to the profession of teaching. A majority of teachers or 83% of the teachers have more than five years in the teaching profession. In addition, more than three-fourths (76%) of the STEAM teachers in the study reported their favorite subjects to teach were math-sciences-technology based courses and one-fourth of the teachers reported liberal arts or reading as their favorite subjects to teach. The grade levels represented by the 93 teachers included the following distribution summary: The school district is comprised of 29 schools including 5 high schools, 6 middle schools, and 18 elementary schools. Each of the 29 schools had at least three designated STEAM teachers comprising the 93 teachers.

3.2 Pedagogical Discontentment Pre and Post Assessment Results and Discussion.

Results of the pre and post assessment pedagogical discontentment assessment mean scores on the *STPDS* (Southerland et al., 2016) for academic year one (2015-2016) and academic year two (2016- 2017) are presented in Table 2. Dependent t tests performed on the total pre and post pedagogical discontentment scores measured by the *STPDS* (Southerland et al., 2016) for the 93 STEAM teachers from year one (2015-16) and year two (2016-17) are also reported in Table 2.

Table 2: *Dependent t-test Results from Pre and Post Assessments for STEAM Year One (2015-2016) and STEAM Year Two (2016-2017) Teachers' Professional Development (N=93) Mean Values for Pedagogical Discontentment Scale (STPDS, 2012)*

Years One and Two	STPDS Pretest		STPDS Posttest			95% CI for Mean Differences			
	Mean	*SD*	*Mean*	*SD*	*N*	*Mean*	*Lower & Upper*	*r*	*t (p-value) df*
2015-16	50.9	15.8	42.3	12.9	93	8.5	4.8 to 12.2	0.5	4.6 (p<.001) 92

Years One and Two	STPDS Pretest		STPDS Posttest			95% CI for Mean Differences			
	Mean	*SD*	*Mean*	*SD*	*N*	*Mean*	*Lower & Upper*	*r*	*t (p-value) df*
2016-17	45.5	13.8	41.6	14.2	93	3.9	0.9 to 6.8	0.5	2.6 (p<.01) 92

Results depicted in Table 2 provide empirical evidence supporting significant decreases in teachers' pedagogical discontentment levels from pre to post assessment periods annually and from year one to year two. Results of the paired samples t-tests show that mean *STPDS* (Southerland et al., 2016) pedagogical discontentment levels of STEAM teachers decreased significantly (p<.001) from before the implementation of the STEAM curriculum program with (M= 50.9, SD = 15.8) and after the implementation of the STEAM Program (M= 42.3, SD = 12.9) in Year One (2015-2016). Likewise, the findings indicate a significant (p<.01) decrease in teachers' pedagogical discontentment within the school district in Year Two with the following changes (M= 45.5, SD = 13.8) for Year Two pre-assessment and (M= 41.6, SD = 14.2) for Year Two (2016-2017) post-assessment. Therefore, significant decreases (p<.01) in teachers' pedagogical discontentment levels were evidenced in both years one and two of the STEAM program implementation with the gap in the means moving toward closure in year two pre and post *STPDS* (2012) pedagogical discontentment assessments.

Resulting decreases in pedagogical discontentment levels of the STEAM teachers may be attributed to time spent in teaching topics focused within the areas of science, technology, engineering, art and mathematics as well as other contributing factors. Livingston, Schweisfurth, Brace, & Nash (2017) proclaimed "pedagogy interacts with and draws together beliefs about learners and learning, teachers and teaching, and curriculum" (p. 8). Taylor (2015), an international advocate for the development of socially responsible and culturally contextualized science and mathematics education, provided a strong rationale for why STEAM is "not just another curriculum fad but an important response to the pressing need to prepare young people with higher-order abilities to deal positively and productively with 21st century global challenges" (p. 89). Meschede et al. (2017) investigated teachers' professional vision of instructional support within science teaching relative to teachers' pedagogical content knowledge and beliefs and found professional vision and pedagogical content knowledge to be "positively

associated" with practical experience influencing this outcome (p. 167). The authors of the *STPD* (Southerland et al., 2012) overwhelmingly support the use of the tool for describing teachers' affective states, to quantify the construct, pedagogical discontentment, and as an essential component for measuring "teacher learning about messages of reform" (Southerland, et al., 2012, p. 20). Kahveci, Mansour, and Alarfaj (2017) examined the construct validity of the *STPD* (Southerland et al., 2016) with teachers in Saudi Arabia and found that "teachers with low pedagogical discontentment had high levels of intentions to reform" (p. 33) contradicting previous findings by Southerland et al. (2012) concerning teachers within the United States who indicated high levels of discontentment demonstrated teachers' willingness to reform their teaching practices. Additional studies focused on teachers' pedagogical discontentment provide some explanation to these contradictory findings. Southerland, Sowell, and Enderle (2017) performed a qualitative study involving structured interviews with 18 science teachers teaching in grades K-12 in the United States and discovered several commonalities in the teachers' pedagogical discontentment considerations focused in the following areas: ability to teach all students science content, concern over balancing depth versus breadth of content, and capability for assessing student learning. Livingston et al. (2017) proposed seven principles for assessing pedagogy: "learner engagement; mutual respect between teachers and learners; building on prior learning; meaningful classroom interactions; relevance of curriculum; developing skills and attitudes as well as knowledge; and the alignment of assessment with curriculum and learner needs." (p. 3). Taylor (2015) advocated for STEAM professional development as a key factor in influencing teachers' pedagogical discontentment levels because STEAM curricular considerations use "a variety of pedagogical techniques for promoting participatory learning and higher-order thinking skills" in students, thus, possibly decreasing teachers' pedagogical discontentment levels (p. 91). Felicia and Innocent (2017) discuss the use of problem-based learning within the context of solar energy applications (an example of a STEAM propelled instructional tool) as an encouraging sustainable practice in science and as a useful example of 21st century teaching and learning pedagogical considerations for teachers. Taylor (2015) also offered several strong elements of STEAM education that may positively influence STEAM teachers' pedagogical contentment levels:

> STEAM education involves teachers in developing a humanistic vision of 21st century

> education and their role as professionals; STEAM education provides a creative design space for teachers in different learning areas to collaborate in developing integrated curricula; STEAM education engages students in transformative learning which is based on five interconnected ways of knowing: cultural self-knowing, relational knowing, critical knowing, visionary and ethical knowing, and knowing in action. (p. 92).

Ferrer (2016) provided a detailed explanation of the inherent need for instruction in mathematics to be sequentially appropriate within the context of students learning integral Calculus by investigating the influence of trigonometry or prior skills as prerequisite learning. Meschede et al. (2017) empirically supported the interrelationship of teachers' pedagogical content knowledge and teachers' professional vision. McDonald (2016) explored differences in pedagogical vision of science teachers versus pre-service science teachers and found large gaps with pre-service teachers' STEAM pedagogical implementation skills substantially weaker than existing science teachers. Kahveci, Kahveci, Nasser, & Maher (2017) findings refuted the existing premise that teachers' pedagogical discontentment levels and intention to reform are enhanced by increasing the number of professional development experiences of teachers, whereas, Taysever (2016) indicated differences in pre and post survey results of STEAM teachers engaged in an online STEAM professional development course revealed increases in teachers' STEAM self-efficacy levels. The current study utilized classroom observations as the method for assessing pedagogical practices within the classroom using external observers.

3.3 Results from Classroom Observations and Discussion.

Descriptive quantitative results of the N= 93 teachers' classroom observations for years one and two of the current research included 847 observations conducted in year one (2015-2016) and 854 observations performed in year two (2016-2017) by eight trained research observers with a resulting interrater reliability coefficient of Pearson $r = .82$ ($p < .01$). The classroom observations consisted of the information and procedures summarized in Table 3.

Table 3. *Sample Key Elements of the Classroom Observation Form*

Focus Areas for Observer Ratings	**Descriptive=1**	**Emerging=2**	**Developing=3**	**Accomplished=4**
Creative Preparation				
Creative Inquiry				
Critical Thinking Integration				
Critical Thinking Problem-Solving				

Critical Thinking Logical Skills				
Communication Data & Info Col				
Communication Argumentation				
Collaboration Team Work				
Collaboration Investigation Skills				

Trained observers (university Ed. D. students) visited all STEAM classrooms for 15-minutes twice a week for the duration of the two years using the form depicted in Table 4. A total of 1285 observations were completed in each of the two years (2015-16 and 2016-17). The resulting percent of the classroom observation data are presented in Table 4 with year one listed as the percent of presence of the rating on the left and the year two percent of presence is listed on the right side of the small box contained within the bottom of each cell listed in Table 4.

Table 4. *Summary Descriptions of the Two Major Observation Ratings for Classrooms of the STEAM Initiative (2015-2016 is listed on the left or first and 2016-2017 is listed on the right or second) within the right lower corner of each cell for each of the observation categories*

	Descriptive Rating = 1	**Emerging Rating = 2**
Creative Preparation	Lessons incorporated opportunities for students to investigate local and global issues, universal problems, and transdisciplinary ideas. **66% 30%**	The teacher designs guided experiences to support disciplinary core ideas and practices and academic content standards. The teacher designs interdisciplinary lessons that involve local & global issues and universal problems. However, students are asked to follow directions to come to a solution. Students are guided in providing examples **24% 61%**
Creative Inquiry	Students are taught and expected to ask questions, identify problems, seek appropriate resources, and persevere in problem-solving. **66% 34%**	Inquiry is teacher directed or guided and is limited to a set process. The teacher designs or provides opportunities for students to learn understanding inquiry begins with a question. **22% 56%**
Critical Thinking Integration	Learning experiences are transdisciplinary in nature and focus on authentic content connections, and current real-world issues within the context of multiple **71% 38%**	The teacher plans experiences that focus on a common theme but stay within the content boundaries. The teacher leads students through prompted discussions associated with a problem or question. The teacher plans lessons that incorporate skills and concepts across two subject areas. **20% 52%**

	disciplines	
Critical Thinking Problem Solving	Students are taught and expected to construct explanation, design, solutions, and solve problems using textual and empirical evidence. **50% 40%**	The teacher leads instruction on constructing explanations, designing solutions, and solving problems using evidence. The teacher provides students with resources that provide explanations and solutions based on evidence. The teacher guides students to find supporting evidence. **28% 56%**

Critical Thinking Logical Skills	Students are taught and provided opportunities to think logically, abstractly, and quantitatively. **50% 44%**	The teacher provides students with experiences to explore quantitative and qualitative data. Students are given opportunities to measure quantities, study patterns, create charts and graphs, and apply computations. The teacher provides lessons to support students' development as logical, abstract, and quantitative thinkers **33% 50%**
Communication Data and Information Collection	Students are expected to choose appropriate mediums and sources to gather, synthesize, evaluate, and communicate data and information. **48% 36%**	The teacher guides experiences that require students to interact with a specific set of media sources ad types. The teacher provides instruction around text and media features that allow students to identify pertinent and accurate information. The teacher guides students to synthesize and evaluate information and data. **33% 56%**
Communication Argumentation	Students engage in constructive argumentation. Students taught and expected to analyze and defend their thinking **69% 66%**	The teacher provides instruction on constructing and analyzing arguments. The teacher provides students with activities in which they explain how data support their arguments. The teacher guides students in analyzing personal arguments of others for flawed reasoning, bias, or misconceptions **11% 28%**
Collaboration Team Work	Students work together to solve problems, develop ideas, and achieve goals. **60% 65%**	The teacher plans experiences in which students are required to work in collaborative groups. The teacher provides guidance on how to work in collaborative groups. Students follow the duties of specific roles within group activities.. **22% 31%**

Collaboration Investigation Skills	Students are taught and expected to plan and carry out investigations. **57% 47%**	The teacher suggests approaches for student to use to answer questions or solve problems. The teacher selects technological tools and methods that are relevant to the investigation. **22% 46%**

Findings reported in Table 4 reveal an overwhelmingly positive observed change over the two-year period within classroom environments in favor of supporting the underlying initial skills for the nine key areas of focused observational areas recorded by the external observers. Results indicate an expanding of observed classroom ratings from describing to emerging in the year two efforts of the STEAM teachers. Observed changes in classrooms moving away from descriptive observed behaviors and toward emerging STEAM behaviors and activities are reported for the nine areas of creative preparation, creative inquiry, critical thinking integration, critical thinking problem-solving, critical thinking logical, communication data and information collection, communication argumentation, collaborative team work, and collaboration investigation skills. Lower percentages of descriptive ratings for year two as compared with year one for each of the nine key areas of observations provide some empirical evidence of engaged teachers and students within STEAM classrooms over time. Notable increases from year one to year two for percentages for emerging ratings also demonstrates a strong effort by STEAM teachers of embracing and moving forward in the plan of actively integrating STEAM into the curriculum. The emerging observed behaviors of teachers and students within the STEAM classrooms also provides some empirical evidence in support of teachers' pedagogical contentment levels emerging within the classrooms observed. Livingston et al. (2017) supported the use of classroom observation as an appropriate tool for "gathering information to inform progress" toward "pedagogy monitoring" through "external evaluation" for the "alignment of curriculum, pedagogy, and assessment" (p. 4). Southerland et al. (2016) also supported the use of classroom and teacher observation as a key element for assessing teaching practices and utilized three external observers to assess teacher practices over a five-year period as relevant information for contributing to changes in pedagogical discontentment levels. Global evidence of the use of classroom observation as a key element for examining teachers' pedagogical alignment within the framework of assessment, strategic planning, management, and communication-engagement was identified as one type of quantitative measure for assessing teachers' pedagogical improvements (Livingston et al., 2017).

Current study results indicate a positive substantial change in observed STEAM classrooms and activities, teacher and student behaviors, and interactions over time. These results align with Southerland et al. (2012) suggestion that teachers' affective states influence their practices in the classroom. Observational results from the current study also align with Meschede et al. (2017) conclusions highlighting "the interrelation of professional vision, declarative pedagogical contentment knowledge (PDK) and beliefs as stable facets of teacher cognition" across both in-service and pre-service teachers (p. 168). The current study results support the efforts of the developers of the *STPDS*: *Science Teachers' Pedagogical Discontentment Scale* (Southerland et al. 2016) by aligning classroom observation data with STEAM teachers' group pedagogical discontentment levels over time. Observational data also contribute to descriptively responding to RQ2: What factors introduced into the implementation of a K-12 STEAM education initiative into a school district influence teachers' pedagogical discontentment? Teachers charged with incorporating creativity, critical thinking, communication, and collaboration as areas mandated by the district for STEAM teachers may experience anxious feelings for teachers unaccustomed to "thinking out of the box" of textbooks and curricular lesson plans.

Results of Coaching STEAM Teachers' Perceptions and Discussion.

The need for science and STEAM teachers' professional development activities to be up-close and personal relative to their effectiveness for teachers to attend to reform efforts was the focus of the work of several researchers (Habegger & Hodanbosi, 2011; Newell, Marchese, Ramachandran, Sukumaran, & Harvey, 1999; Southerland et al., 2016). Personal professional development involvement in the form of peer coaching activities is supported in the literature. Types of peer coaching used as professional development practices have involved multiple kinds of approaches. Peer coaching may involve collaborations among faculty departments, e.g., a communications department within a higher education institution collaborating with an engineering department focused on delivering best practices for engineering activities and experiments with undergraduate students and communications department faculty members assisting students in the writing activities for documenting the engineering activities or experiments. Cloutier (2016) found the use of instructional coaches for elementary teachers to be the most effective type of professional development for promoting science related education activities. Habegger & Hodanbosi (2011) found that teachers in a Midwestern school district within the United States were open to new strategies, new materials, and working with new coaches. These prior literature results provide an initial supporting statement and segue to the current study use of professional STEAM coaches for the N= 93 STEAM teachers as a resource for their individual professional development over the two year study period. STEAM teachers were provided access as needed to individual STEAM coaches. The average usage of STEAM coaches by the STEAM teachers was approximately 2-3 times per week for lesson modeling and/or discussion of pedagogical questions. All STEAM teachers were allowed to assess their coaches at the end of the two-year period using an instrument developed by the researchers. Results of the STEAM teachers' assessments of their coaches are presented in Table 5.

Table 5: *Frequencies of N= 93 STEAM Teachers' Perceptions of Their Instructional Coaching Experiences for the Summation of the Two-Year Period of the Study*

My coach was accessible	f	%		My coach demonstrated professional integrity	f	%
Strongly Disagree	5	5%		Strongly Disagree	5	5%
Disagree	0	0%		Disagree	0	0%
Slightly Disagree	0	0%		Slightly Disagree	1	1%
Slightly Agree	4	4%		Slightly Agree	1	1%
Agree	17	18%		Agree	11	12%

Strongly Agree	67	73%		Strongly Agree	75	81%
TOTAL	93	100%		TOTAL	93	100%

My coach demonstrated content expertise	f	%		My coach was approachable	f	%
Strongly Disagree	5	5%		Strongly Disagree	5	5%
Disagree	0	0%		Disagree	0	0%
Slightly Disagree	1	1%		Slightly Disagree	0	0%
Slightly Agree	2	2%		Slightly Agree	1	1%
Agree	22	24%		Agree	14	15%
Strongly Agree	63	68%		Strongly Agree	72	78%
NA	0	0%		NA	1	1%
TOTAL	93	100%		TOTAL	93	100%

My coach was supportive and encouraging	f	%		My coach provided constructive feedback	f	%
Strongly Disagree	5	5%		Strongly Disagree	4	4%
Disagree	0	0%		Disagree	0	0%
Slightly Disagree	0	0%		Slightly Disagree	2	2%
Slightly Agree	1	1%		Slightly Agree	7	8%
Agree	12	13%		Agree	26	28%
Strongly Agree	74	80%		Strongly Agree	50	53%
NA	1	1%		NA	5	5%
TOTAL	93	100%		TOTAL	93	100%

My coach motivated me to improve my work	f	%		My coach was helpful in providing direction	f	%
Strongly Disagree	5	5%		Strongly Disagree	5	5%
Disagree	0	0%		Disagree	0	0%
Slightly Disagree	1	1%		Slightly Disagree	1	1%
Slightly Agree	3	3%		Slightly Agree	7	8%
Agree	23	26%		Agree	25	27%
Strongly Agree	58	62%		Strongly Agree	52	56%
NA	3	3%		NA	3	3%
TOTAL	93	100%		TOTAL	93	100%

Findings depicted in Table 5 provide insight into the interrelationships of the N= 93 STEAM teachers and their instructional coaches. The coaches were hired by the school district from a private company focused on STEAM professional development. Twenty instructional STEAM coaches were provided by the school district for the 93 STEAM teachers to use as needed for lesson modeling or for individual questions regarding STEAM instructional considerations, content information, or pedagogical concerns. Resulting frequencies depicted in Table 5 provide the following descriptive information regarding STEAM teachers' perceptions of their

instructional coaches: (a) more than 90% of the teachers agreed their coaches were accessible, demonstrated professional integrity and content expertise, approachable, supportive and encouraging, provided constructive feedback, and suggested appropriate resources; (b) 85 to 89 percent of the teachers indicated their coaches motivated them to improve their work, answered their questions satisfactorily, acknowledged teachers' contributions, and challenged teachers to extend their abilities. These positive findings provided the school district with information regarding the positive impact of STEAM coaches on STEAM teachers' instructional contentment. STEAM teachers were overwhelmingly appreciative of the STEAM coaches. These results may lend some evidence to the possible positive impact of professional coaching on STEAM teachers' reductions in pedagogical discontentment levels over the two-year period. Krueger (2014) recommends a "pedagogical approach to coaching" teachers in the classroom relative to the integration of new technologies whereby the coach serves as a "learning partner" with teachers rather than as an expert (ISTE.org blog). Knight (2007) developed the partnership coaching model and became known as a key source for promoting educational coaching in the United States. Knight (2007) researched seven principles for his philosophy of partnership coaching for educators: "Equality, Choice, Voice, Dialogue, Reflection, Praxis, and Reciprocity" (pp. 37-54). Although the use of coaching for professional development in addition to many other types of formal professional development experiences were included in the current study, the use of coaches was considered by the STEAM teachers to be the most helpful type of professional development because of the partnership approach and the Just-In-Time nature of the professional development. Knight's (2007) description and discussion of "Praxis" or "connecting new strategies to practice" by using coaches aligns with teachers' pedagogical contentment levels within the current study (p. 49).

4 Summary, Limitations, and Conclusions

4.1 Summary

The current two-year quantitative study examined the influence of the implementation of various Science, Technology, Engineering, Art, and Mathematics (STEAM) professional development venues on N=93, K-12 teachers' pedagogical discontentment levels within a school district located in the southeast region of the United States. Assessment results gathered within the study included a demographic assessment of the teachers' ages, years of experience, gender, ethnicity, highest degree held, and favorite teaching subjects. Professional development

provided by the district throughout the two-year period focused on the implementation of the STEAM curriculum, included periodic workshops aimed at STEAM content, instructional strategies, developing STEAM classroom activities, lesson modeling, and the use of professional instructional coaches for the teachers. Pre and post assessments of the 93 STEAM teachers relative to their pedagogical discontentment using the *Science Teachers' Pedagogical Discontentment Scale (STPDS)* (Southerland et al., 2016) was conducted at the beginning and the end of each of the two academic years to determine changes in the STEAM teachers' average pedagogical discontentment levels over time. STEAM classroom observations (N= 1701) were conducted throughout the two-year period periodically to also determine changes in instructional practices over time. Classroom observation data provided descriptive information relative to the types of instructional context and classroom instructional changes potentially influencing teachers' pedagogical discontentment. Teachers' assessments of their instructional coaches were also reported relative to areas of instruction potentially influencing teachers' pedagogical discontentment levels. Findings indicate significant ($p<.01$) decreases in teachers' pedagogical discontentment levels from pre to post assessment times for year one and year two of the study with the mean gap lessening from pre to post assessment for year two. Classroom observation data revealed teachers implementing creativity, critical thinking, and collaboration activities and gradually corroborated the teachers' pedagogical discontentment decreases by determining solid positive changes from descriptive instructional classrooms to emerging STEAM reformed classrooms for all areas indicative of STEAM learning environments providing some external data supporting positive teachers' pedagogical contentment levels. STEAM teachers' consistently high positive assessments of their instructional coaches also provide evidence of STEAM teachers' positive pedagogical contentment levels.

4.2 Limitations

Limitations of the current study include the following considerations: (a) The 93 STEAM teachers voluntarily applied for the opportunity to serve as the new STEAM teachers for the school district prior to the initiation of the study and were not provided any additional compensation for serving as STEAM teachers, therefore, school districts that mandate teachers to implement a STEAM curriculum may have very different results from the current study findings; (b) The school district provided the required professional development activities for all 93

selected STEAM teachers with no input or descriptive information provided to the researchers, therefore, study findings cannot be reported within the context of the specific types of professional development workshops, institutes, and personal coaching activities provided for the STEAM teachers; (c) The resulting homogenous demographics indicating a specific type of STEAM teacher (overwhelmingly white females with less than 15 years of teaching experience) of the 93 STEAM teachers must be considered relative to the findings of the study; and (d) using the *STPDS* (Southerland et al., 2016) at the beginning and end of each school year as the same pre and post assessments may have allowed teachers to remember specific items rather than replying according to their true feelings of discontentment.

4.3 Conclusions

Livingston et al. (2017) and Taylor (2016) projected the strong need for support for the role of pedagogy in examining global education in 2030 by focusing on monitoring and improving pedagogy, and quantitatively measuring specifically agreed upon indicators. The current study provides empirical evidence in support of three types of indicators to meet the 2030 goal: (1) use of an assessment tool (Southerland et al., 2016) for measuring K-12 STEAM teachers' considerations relative to pedagogical reform efforts over time; (2) use of classroom observations aimed at examining factors specific to K-12 STEAM teachers' implementation of STEAM into the 21st century K-12 curriculum; and (3) use of coaching STEAM teachers by external STEAM coaches. RQ1 (How does the immersion of K-12 teachers into a school district-wide STEAM program impact the pedagogical discontentment levels of the teachers?) was empirically supported indicating a district-wide approach of teachers moving toward a STEAM culture. RQ2 (What factors introduced into the implementation of a K-12 STEAM education initiative into a school district influence teachers' pedagogical discontentment levels?) was described within the context of classroom observational data results showing a gradual movement of STEAM teachers toward embracing instruction with creativity, critical thinking, and collaboration.

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