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Assessment of Creativity in Arts and STEM Integrated Pedagogy by Pre-service Elementary Teachers

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In education, mathematics and science are often taught in a manner that lacks opportunities for students to engage in creativity, and the arts are allotted less time with fewer resources. This study focused on integrating STEM (science, technology, engineering, and mathematics) lessons with arts-themed activities to create interdisciplinary STEAM education in order to simultaneously address these two contemporary challenges. Teams of pre-service elementary teachers used multimedia production technologies to develop original STEAM lessons. Participants (n = 124) completed a total of 2,436 peer-evaluation surveys designed to measure the extent to which the STEAM lessons met specific creativity-related objectives. Participants also answered open-ended questions regarding similarities and differences between their own STEAM lessons and those of the other teams. The results showed general overall similarities among the three participating groups of bilingual generalist (BG), regular generalist (RG), and undecided generalist (UG) pre-service elementary teachers in regard to their peer evaluation scores for achievement of creativity-related objectives in the STEAM lessons.

In addition, a substantial portion of participants from each group recognized the two highest and two lowest scoring achievement categories in their discussions of similarities and differences, and this qualitative data assisted in confirmatory triangulation of the quantitative findings.

INTRODUCTION

Two prominent problems in education today are: (1) mathematics and science lessons are often taught in a manner that lacks opportunities for students to engage in creativity (Berry, Bull, Browning, Thomas, Starkweather, & Aylor, 2010); and (2) the arts and other creativity-focused subjects are allotted less time with fewer resources (White & Garcia, 2010). In the present study, STEM (science, technology, engineering, and mathematics) lessons were integrated with arts activities to create an interdisciplinary STEAM (science, technology, engineering, arts, and mathematics) pedagogy that addresses both problems.

The STEAM framework is by no means the only approach to disseminating more creativity into schools; however, it does present an interesting opportunity from a research perspective. Specifically, the STEAM framework allows for analysis of creativity manifested during the intentional placement of the arts into interdisciplinary STEM-themed education. Towards this end, the participants in the study were pre-service elementary teachers who learned as part of the study intervention how to employ digital media production technologies to create STEAM lessons with accompanying multimedia.

This study is part of a larger NSF-funded research project that aims to improve the pedagogical content knowledge of pre-service and in-service primary school teachers by teaching STEM content through interdisciplinary approaches. Several of the previous studies within this line of inquiry have examined STEAM lessons as an opportunity for instantiating authentically engaging contextualized mathematics education, including examination of impacts from contextualized mathematics education wherein upper-elementary students designed and built models of NASA satellites and rockets (Tillman, An, Boren, & Slykhuis, 2014), as well as examination of impacts upon middle-grade students that created environmentally friendly wind turbine designs and prototypes for generating renewable power (Tillman, An, Cohen, Kjellstrom, & Boren, in press). Other examples of studies pursued within this line of inquiry have included examinations of effects from in-service teachers integrating music-themed design activities

into regular mathematics lessons (An, Capraro, & Tillman, 2013), as well as impacts from pre-service teachers learning to teach mathematics through music-themed design activities (An, Ma, & Capraro, 2011). The studies that have been conducted within this line of inquiry were deeply influenced by previous research examining effects from contextualizing mathematics education, including studies that have analyzed the use of: aesthetics in mathematics education (Betts, 2005), children's literature to support contextualization of early childhood mathematics (Keen, 2003), and the affordances of employing children's engineering activities as a context for contextualized mathematics pedagogy (Bull, 2012),

In the present study, small teams of pre-service elementary teachers developed STEAM integrated lessons, which were then evaluated by all participants. The results of peer evaluation were analyzed and compared according to teacher specialization group. To clarify, the term *team* in this paper refers to a set of three or four participants who co-designed STEAM lessons and materials, whereas the term *group* refers to participant status as a pre-service elementary teacher on track for certification in one of three categories: (1) bilingual generalists (BG), meaning those who are preparing to teach in both Spanish and English at dual-language elementary schools, (2) regular generalists (RG), and (3) undecided generalists (UG), meaning those who are enrolled in an elementary education program in a college of education but have not yet committed to either track. Most teams contained a mix of BG, RG, and UG participants. Given that UG students will eventually chose one or the other track of RG or BG, results from the UG students were analyzed to determine if they met the expectation of representing a mixture of the RG and BG responses.

The rationale for focusing upon any differences between BG, RG, and UG participants was that evidence in the literature steadily shows that the conventional pedagogical approach to mathematics methods that pre-service teachers are indoctrinated into is not serving all students equally well; specifically, historically underserved populations such as female and minority students are often disadvantaged during conventional instruction (Hiebert & Grouws, 2007). The present study was undertaken to help partially address these issues by providing insights into any differences between BG and RG pre-service teachers that would justify differentiating aspects of their preparation during mathematics methods courses.

The purpose of this study was to assess group differences in peer evaluation and assessment of STEAM lessons and materials regarding opportunities for students to engage in creativity, as displayed by BG and RG pre-service teachers. Within the context of contemporary American society,

wherein this study took place, Hispanics are the fastest growing minority population and are increasingly serving roles in K-12 education as well as other fields related to education. To gain an understanding of the participants' attitudes towards creativity in the mathematics classroom, a survey was developed to assess multiple aspects of their perceptions of creativity opportunities within the lessons developed by their classmates. Items in the peer-evaluation survey were designed to measure the extent to which the STEAM lessons and materials achieved seven creativity-related objectives: creatively innovative, creatively connected, creatively enjoyable, creatively challenging, creatively integrated, creatively equitable, and creative choices. For example, the survey item for *creatively innovative* was "Do the lessons creatively demonstrate innovative ways of teaching mathematics or science?" In addition, participants answered open-ended questions regarding similarities and differences among STEAM lessons developed by the various teams.

LITERATURE REVIEW

This section presents a review of previous findings from multiple interrelated lines of research that form the basis for the present study: (1) a definition of creativity within the context of STEAM-themed education, (2) background about why multimedia is a suitable choice for facilitating creativity during STEAM-themed education, (3) information contextualizing this study within the TPACK framework, (4) differences between RG and BG elementary school teachers in terms of attitudes and beliefs regarding math and science education, (5) undergraduate preparation of RG and BG elementary teachers in terms of pedagogical approaches and attitudes towards STEM, and (6) the long-term impacts of STEM pedagogy and teacher attitudes on students in terms of student STEM achievement and attitudes during elementary school and beyond. The synthesis of these six topics forms a foundation for the present study, wherein the dual problems discussed in the introduction—an increasing lack of arts education coupled with an increasing lack of creativity in STEM education—are both addressed via an interdisciplinary STEAM approach that plants creativity firmly in the classroom as a means for instantiating authentically engaging contextualized mathematics education.

Defining Creativity within the Context of STEAM-themed Education

Defining creativity within the context of STEAM-themed education is a complex task, and we do not claim to have a definition that is exclusive; rather, we employ Csikszentmihalyi's general definition of creativity, paraphrased from *The Systems Model of Creativity* (2014) as *the process of producing something original and worthwhile*. This is in agreement with the prevalent popular definition presented by Mumford (2003) that "creativity involves the production of novel, useful products" (p. 110). However, we believe Csikszentmihalyi's use of the term *worthwhile* is preferable to Mumford's term *useful* because the first term is more all-encompassing; for illustration, anything useful is by definition worthwhile, but sunsets are worthwhile even though they are not useful. The survey instrument was developed within this context, as appropriate themes were chosen and then modified to suit the assessment of creativity in an interdisciplinary STEAM pedagogy; specifically focusing upon whether the STEAM lessons and materials were creatively innovative, creatively connected, creatively enjoyable, creatively challenging, creatively integrated, creatively equitable, and provided creative choices.

Employing Multimedia to Facilitate Creativity during STEAM-themed Education

Facilitating the provision of opportunities for creativity during STEAM-themed education requires, by definition, that the students be given the time and materials to participate in the process of producing something they feel is original and worthwhile (Csikszentmihalyi, 2014). If the "originality" is actually rote and superficial, or the "worthwhile"-ness is inauthentic because the student is really only trying to earn a high grade or please an adult, then the students are producing artifacts that appear creative but are in fact not the result of a creative process. Rather they are engaging in a copy-and-paste assembly-line process that is closer to the bulk production of cheap manufactured goods than to the desired ambition of actual creative engagement.

Creativity in the classroom is a noble, but ancient, aspiration—it is difficult to imagine a respected teacher at any point in history that was against students displaying *any* creativity in the classroom. Rather, what differentiates teachers is what they define as positive productive creativity that is pedagogically appropriate, versus counterproductive creativity such as graffiti. By channeling students' creativity, as well as their teachers' desire to nurture

educationally appropriate creativity, well-prepared teachers can design constructive outlets for their students. However, to address the logistical and financial obstacles involved, low-cost scalable media are required—of which digital multimedia is currently the state-of-the-art among the choices available.

Contextualization within the TPACK framework

The TPACK (technological, pedagogical, and content knowledge) framework provides a theoretical background against which to understand effective utilization of digital multimedia in the classroom. TPACK acknowledges that the most effective use of a technology, such as digital multimedia production, in the classroom is as part of a system that enhances the dual aspirations of high-quality pedagogy and content knowledge (Mishra & Koehler, 2006). The TPACK theoretical framework thereby provided a context for examining the participants' ability, according to their own self-assessments, to create lessons that engage students in opportunities for creativity within STEAM-themed instruction.

This study was undertaken with the intention of employing the results obtained to inform suggestions for improving the pedagogical-content-knowledge preparation of pre-service teachers undergoing instruction about educational technology. Particularly, the emphasis was upon preparing them to utilize digital multimedia production technologies to create STEAM-themed lessons that gave their own future students opportunities to be creative. Within this context, the study's specific focus was on analyzing any differences between the participants that were regular and bilingual education elementary teachers; the next section will explain why we decided to stress this issue.

Differences between Regular and Bilingual Education Elementary Teachers

Preparing elementary teachers for Hispanic and other ESL (English as a Second Language) immigrant children is a challenge that has been addressed by education researchers through several approaches, including: a service learning approach (Bollin, 2007), immersion in international field experiences involving overseas student teaching experiences (Mahon & Cusher, 2002), and quantitative analysis of the impact of gender and race on the perceptions and experiences of pre-service teachers in such settings

(Phillion & Malewski, 2009). Studies with pre-service teacher participants have analyzed the impacts of a field immersion program on attitudes toward teaching in culturally diverse classrooms (Wiggins, Follo, & Eberly, 2007), as well as the impacts upon pre-service teachers from a technology supported virtual field experience interacting with diverse populations in remote locations (Phillion, Miller, & Lehman, 2005). Other researchers have focused on determining the factors that serve as predictors of elementary teacher candidates' attitudes toward diversity (Burriss & Burriss, 2004) and attitudes toward ESL students (Youngs & Youngs, 2001). Elementary teachers that report having achieved success in their own K-12 mathematics education often identify family support as a factor in their success, implicitly acknowledging that sociocultural factors can either promote or restrict learning; however, they also frequently hold the inaccurate belief that mathematics ability is inherited (De Freitas, 2008).

Within the context described, the most salient difference between RG and BG elementary teachers—by definition—is that RG teachers are prepared to teach STEM subjects in the regular (i.e., English-speaking) classroom whereas BG teachers are prepared to teach in both Spanish and English at dual-language elementary schools where the students are often ESL learners. The necessity of teaching in two languages is an extra responsibility that BG teachers carry in addition to their regular teaching duties, and their self-confidence in their own ability to achieve these responsibilities in the classroom with their students has been termed *self-efficacy* (Bandura, 1977). Teacher self-efficacy is a key component of effective STEM teaching that contributes to student STEM achievement and the development of positive attitudes towards STEM among students (Tyler-Wood, Knezek, & Christensen, 2010). Most elementary teachers understand that for students to achieve success in STEM, the students must develop not only specialized content knowledge (Ball, Hill, & Bass, 2005) but also durable positive dispositions towards STEM subjects (Lajoie, 2003), particularly mathematics (Sadler & Tai, 2007). These factors can be negatively impacted by poor pedagogical self-efficacy on the part of teachers in regard to teaching mathematics and other STEM subjects (Gunderson et al., 2012). Achieving high self-efficacy for subject areas that involve complex symbols and concepts, such as mathematics and science, can be more challenging for BG elementary teachers, who must teach these subjects in two languages (Spina, 2006).

Development of Elementary Teacher STEM Pedagogy and Attitudes

Undergraduate- and graduate-level teacher education programs across the country prepare pre-service teachers to enter the classroom and assume the responsibilities of an in-service teacher. Pre-service middle school and high school teachers often specialize in an area of active interest, as evidenced by their enrollment in an education program that prepares them for pedagogical specialization (Jones-Kavalier & Flannigan, 2008). However, pre-service elementary school teachers are most often generalists who are responsible for teaching multiple subject areas, including a foundation of basic skills colloquially referred to as "the three Rs" (reading, writing, and arithmetic; Midgley, Anderman, & Hicks, 1995). Thus, the archetypal elementary teacher is someone who prefers generalization rather than the type of specialization involved in teaching more advanced subjects, such as mathematics and science, in secondary education (Lajoie, 2003).

While many generalist teachers are fully competent, high-quality mathematics educators, others are less prepared. Evidence in the literature consistently shows that the traditional mathematics curricula and instructional methods taught to pre-service teachers are not serving all students equally well, particularly historically underserved populations such as female and minority students (Hiebert & Grouws, 2007). Developing high-quality math and science teachers has been identified by the Education Alliance and other research organizations as a crucial component for improving student mathematics and science achievements in the US and thereby closing the academic achievement gap (Education Alliance, 2006). The design of the present study was created with the intent of helping to address these issues, with specific emphasis upon supporting the teacher education research community's understanding of any differences in the peer-review assessments of STEAM lessons created by RG and BG pre-service teachers, as well as the implications upon teacher education of such differences.

Impact of Elementary Teacher STEM Attitudes on Students

Undergraduate students enrolled in a college of education who are studying to become in-service elementary teachers are the future instructors of primary students during their earliest years of formal education. Extensive research has demonstrated that primary school teacher attitudes towards mathematics and science influence STEM attitudes and achievements among elementary students (Berry et al., 2010). In addition, multiple em-

pirical studies of students and teachers have reported that a major barrier to developing positive attitudes towards mathematics is the presence of persistent math-related anxiety (Bursal & Paznokas, 2006). Research in this area has often focused on interventions designed to reduce student math anxiety (Knezek, Christensen, & Tyler-Wood, 2011) and to improve the assessment of student math anxiety (Tyler-Wood et al., 2010). Thus, reducing math anxiety and increasing positive attitudes towards STEM are two important approaches for improving academic performance in STEM subjects.

Efforts to reduce student math anxiety and increase positive attitudes towards STEM have involved contextualized mathematics education that is designed to engage students in learning mathematics via connections with their real-life interests and ambitions (An, Ma, & Capraro, 2011; Cohen et al., 2012; Slykhuis et al., 2012). This approach attempts to alleviate shortcomings that are often associated with teaching abstract mathematical concepts that are decontextualized from students' real-life experiences and interests (Kjellstrom, Tillman, & Cohen, 2012). Students who are disengaged from mathematics education often have trouble learning mathematics due to the lack of relevant connections with their existing knowledge and out-of-school experiences, resulting in reduced student motivation, reduced engagement with mathematics topics, and negative attitudes towards mathematics (Sherman & Wither, 2003). Research has shown that for effective contextualized mathematics education to occur, teachers must have sufficient self-efficacy for teaching the subject within this framework, including self-efficacy in mathematics pedagogy and mathematics content knowledge (Bursal & Paznokas, 2006). Importantly, in order to effectively teach contextualized mathematics, teachers cannot have high levels of mathematics anxiety themselves (Hiebert & Grouws, 2007).

Synthesis and Implications for Contextualized Mathematics via STEAM

This literature review has presented previous findings from three related lines of research that formed the basis for the present study. Synthesis of the implications from the discussed research upon the present study examining an interdisciplinary STEAM approach to embedding creativity into the mathematics curriculum established several relevant particulars: (1) The long-term impacts from quality and nature of STEM pedagogy as well as teacher attitudes on students in terms of student STEM achievement and attitudes during elementary school and beyond are substantial and extensive; (2) if there are differences between BG and RG elementary school teach-

ers in terms of attitudes and beliefs regarding math and science education, those differences might influence their aptitude and willingness to attempt a STEAM approach to contextualizing mathematics; and (3) if so, then preparation of BG and RG elementary teachers should be differentiated in terms of STEAM pedagogical preparation, including perhaps even the decision to employ STEAM pedagogy, to better address these dissimilarities.

The present study was designed to empirically examine the second item mentioned in the previous paragraph (i.e., STEM differences between BG and RG teachers), so as to determine if there is warrant to proceed to research on the third item (i.e., differentiated STEAM pedagogical preparation for BG and RG teachers). Identifying any differences in educational beliefs among these specialization groups might allow for such differences to be strategically addressed. For example, counterproductive misconceptions, such as believing that mathematical ability is innate, may be dispelled through an interdisciplinary STEAM approach wherein the dual problems discussed in the introduction—an increasing lack of creativity in STEM education coupled with an increasing lack of arts education—are both addressed synchronously. While previous studies have investigated the attitudes, beliefs, and self-efficacy of pre-service elementary teachers in relation to STEAM pedagogy, there is a lack of research examining any differences in peer evaluation of STEAM lessons and materials by BG and RG teachers. In the present study this gap in the empirical research will be addressed, with specific emphasis upon determining any group differences in peer evaluation of the achievement of specific creativity-related objectives within STEAM lessons developed by the BG and RG participants.

METHODS

The two primary questions that guided this study were: (1) How did peer evaluations of creativity in STEAM lessons differ between BG and RG pre-service elementary teachers? (RQ1) and (2) How did the perceptions of BG and RG pre-service elementary teachers regarding similarities and differences in STEAM lessons differ? (RQ2).

To answer the two research questions, this study employed a convergent mixed-methods design (Creswell & Plano, 2003; Strauss & Corbin, 1994) in which quantitative and qualitative data were collected, analyzed separately, and then combined during interpretation. Quantitative data included over 2,000 peer-evaluation surveys to address RQ1, and qualitative data consisted of open-ended questions to address RQ2. The study was designed such

that the quantitative findings for RQ1 informed the selection of key themes that were coded and used to analyze the qualitative data for RQ2.

Setting and Participants

This study took place at a large public university in western Texas, with a campus located less than a mile north of the US-Mexico border. The university's undergraduate student population was over 75% Hispanic at the time of this study, which was the highest percentage of Hispanic undergraduates at any public university in the US at that time. The participants were students who were attending a series of required core courses for future RG and BG elementary teachers on the fundamentals of elementary classroom education. Junior and senior undergraduate students with an average age of 26 years populated these courses. A total of 124 predominantly female Hispanic pre-service teachers participated in the study after being recruited from two sections of an introductory teaching methods course. Of the 124 participants, 61 were RGs, 43 were BGs, and 20 were UGs. All participants were informed that this study was being undertaken as part of a larger NSF-funded research project on improving the pedagogical content knowledge of primary school teachers.

Intervention

The intervention for this study included creating STEM lessons that were integrated with arts activities to produce interdisciplinary STEAM education. All participating pre-service elementary teachers were taught how to use digital media production technologies to create lessons as part of the study intervention, and they then worked in small teams (average = 3 participants per team) to produce a series of STEAM lessons with supplementary multimedia using an interdisciplinary arts-themed approach. As students enrolled in an educational technology course, all pre-service teacher participants were provided with a series of lessons and corresponding assignments that helped them develop the digital multimedia production skills and digital materials for creating their own original STEAM-themed lessons.

The teams then presented their projects to the other participants during live presentations where they showcased the lessons and supplementary multimedia including a video designed to highlight the best features of their instructional design. During a brief interval between successive team pre-

sentations, each participant—including those participants whose team had just presented—completed a peer evaluation survey, and then the next group set up and presented. After the presentations were completed, participants then answered a set of open-ended questions regarding their perceptions of the peer evaluation experience. It should be noted that the participants were intentionally combined into mixed groups containing BG, RG, and UG pre-service teachers so as to help ensure comparable experiences during the study, with the understanding that this might impact results obtained. Therefore a follow-up study in which the groups are separated is under consideration.

Instrumentation and Data Collection

The data collection for this study employed both quantitative and qualitative methods, and was designed to facilitate the comparison of BG, RG, and UG pre-service elementary teachers in terms of their survey and interview responses. Quantitative data was obtained using a survey instrument for peer evaluation of STEAM lessons and materials, and qualitative data was obtained using open-ended questions.

The survey instrument was based on those used to assess interest in STEM content and careers (Tyler-Wood, Knezek, & Christensen, 2010). Appropriate themes were chosen and then modified to suit the assessment of creativity in an interdisciplinary STEAM pedagogy. Survey development was also guided by the work of Sadler and Tai (2007), who statistically demonstrated that students' attainment of competence at general mathematics and scientific specialization in high school were key supports for college science success, thereby confirming the importance of helping students undergo positive experiences with learning STEM during their pre-college education.

The TPACK theoretical framework provided a context for developing the peer-evaluation survey, in that the instrument measured creativity of the STEAM lessons by focusing on multiple criteria that collectively equate to a sound combination of technology (represented by digital multimedia production), content (represented by interdisciplinary STEAM lessons), and pedagogy (represented by sound and engaging instruction). Specifically, the peer-evaluation surveys contained seven items scored on a five-point Likert-type scale; during the survey, participants were asked to rank each of the presentations of STEAM lessons and supplemental materials by writing a number score for each question, and the scores were: 1 = *does not achieve*

objective, 2 = *achieves objective a little*, 3 = *achieves objective okay*, 4 = *achieves objective well*, and 5 = *achieves objective with excellence*. The items were designed to evaluate seven creativity-related objectives for the STEAM lessons and materials: creatively innovative, creatively connected, creatively enjoyable, creatively challenging, creatively integrated, creatively equitable, and creative choices. The items (one for each objective) are: (1) "Do the lessons creatively demonstrate innovative ways of teaching mathematics or science?" (2) "Is lesson content closely related to the lesson objectives in a creative manner?" (3) "Was there creativity used in developing an enjoyable learning environment?" (4) "Are there enough creative challenges presented for students?" (5) "Are the arts components creatively integrated with the mathematics or science topics?" (6) "Do the lessons try to creatively create an equitable learning environment that respects all students' ideas?" and (7) "Are there enough choices for students to creatively choose their own ways to solve the problems?" Participants took no more than 5 minutes to complete each survey, and a total of 2,436 evaluation surveys were completed.

After the presentations and peer evaluation surveys were completed, participants answered two open-ended questions about their peer evaluation experiences by typing their responses into a digital text document and then uploading their file to a password protected, cloud-based folder. Specifically, participants were asked: (1) "Describe the similarities between your team's lessons and other teams' lessons in terms of opportunities for students to engage in authentic creativity" and (2) "Describe the differences between your team's lessons and other teams' lessons in terms of opportunities for students to engage in authentic creativity." The reason participants were asked to describe similarities and differences between their own STEAM projects and those of the other students was to deter them from providing answers wherein they only discussed positive or superficial characteristics of the lessons and supplemental materials, rather than addressing the lessons critically and acutely. Based on the phrasing of questions that had resulted in helpful responses during previous studies, having the participants specifically compare similarities and then differences was determined to be a dependable approach to obtaining useful data for this portion of the study. Additionally, participants provided demographic information about age, ethnicity, gender, and other variables.

Data Analysis

Data analysis for this mixed-methods study involved analyzing quantitative and qualitative data separately and then combining the results for interpretation. The aim was to determine whether there were any noteworthy differences among responses from BG, RG, and UG pre-service elementary teachers. Quantitative data was obtained from peer-evaluation surveys completed by participants for each team's presentation of STEAM lessons and multimedia. Analysis of the peer-evaluation surveys was designed to address differences between BG, RG and UG groups in terms of their critiques of the STEAM lessons and materials. Qualitative data from open-ended questions was analyzed to explore participant perspectives on the similarities and differences between STEAM lessons and materials in terms of offering students opportunities to engage in creativity.

Responses from peer-evaluation surveys were tabulated and descriptive statistics were calculated for each of the seven survey items, including mean, standard deviation, and sample size. Results from the BG, RG, and UG groups were then compared to determine whether any differences existed among group scores for achievement of the seven creativity-related objectives.

To provide a context for the quantitative findings, qualitative responses were analyzed using the grounded theory method of axial and selective coding (Strauss & Corbin, 1994). Open-ended responses from 20 participants were randomly selected from each of the three groups (RG, BG, and UG), and responses were coded according to their ability to provide insight regarding the top two and bottom two creativity-related objectives (in terms of successful achievement) that were identified from the quantitative data based on mean score. The top two objectives were coded within the "similarities" answers, and the bottom two objectives were coded within the "differences" answers, and then response frequencies for these four objectives were calculated. The logic for choosing this method was to facilitate determining the consistency of the written answers with the survey responses, namely did the most achieved criteria align with "similarities" and did the least achieved criteria align with "differences", which they should overall if the quantitative and qualitative answers given were consistent. In addition, informative examples of similarities and differences in STEAM lessons and materials in terms of the four objectives were extracted from participant responses.

RESULTS

Quantitative Analysis

Participant responses on the peer-evaluation surveys were tabulated and compared to determine whether any differences existed among the BG, RG, and UG groups' evaluations of the achievement of seven creativity-related objectives for the STEAM lessons and supplemental materials. As noted earlier, each participant completed multiple peer-evaluations, which resulted in the total number of surveys collected including 851 BG surveys, 1,185 RG surveys, and 400 UG surveys. Descriptive statistics including mean and standard deviation for each of the three groups are shown in Table 1.

Table 1

Results from Pre-service Elementary Teacher Participant Surveys by Bilingual Generalist (n = 851), Regular Generalist (n = 1,185), and Undecided Generalist (n = 400)

Item	Bilingual Generalist Mean (St. Dev.)	Regular Generalist Mean (St. Dev.)	Undecided Generalist Mean (St. Dev.)
Creatively innovative	4.208 (0.812)	4.181 (0.847)	4.298 (0.852)
Creatively connected	4.195 (0.800)	4.189 (0.849)	4.258 (0.814)
Creatively enjoyable	4.166 (0.876)	4.138 (0.893)	4.175 (0.892)
Creatively challenging	3.910 (0.949)	3.874 (0.974)	3.952 (0.953)
Creatively integrated	4.046 (0.895)	4.035 (0.942)	4.180 (0.891)
Creatively equitable	4.090 (0.882)	4.055 (0.911)	4.080 (0.936)
Creative choices	3.942 (0.942)	3.882 (1.017)	3.925 (1.028)

The mean scores reflect the scores assigned by participants in each group for all STEAM presentations combined and measure the extent to which the creativity-related objective was achieved in the STEAM lessons. The results show that the three groups had similar, but not identical, scores for achievement of the seven creativity-related objectives. For example, the two highest scoring objectives were the same for all three groups, although in different orders. The objective *creatively innovative* was given the highest score for achievement by the BG and RG groups, but the UG groups gave it the second highest score. Conversely, the characteristic *creatively connected* was given the highest score for achievement by the UG group and the second highest score by the BG and RG groups. Likewise, the two lowest scoring objectives in terms of successful achievement were the same for

all three groups, but in different orders. The objective *creatively challenging* was given the lowest score for achievement by the RG and UG groups, but was scored second lowest by the BG group. Conversely, the objective *creative choices* was given the lowest score for achievement by the BG group, whereas the RG and UG groups gave it the second lowest score.

The RG and UG groups ranked the other three creativity-related objectives in the same order according to score: *creatively enjoyable*, *creatively equitable*, and *creatively integrated* were third, fourth, and fifth, respectively, in terms of successful achievement. The BG group ranked *creatively integrated* in third place, *creatively enjoyable* in fourth place, and *creatively integrated* in fifth place in terms of successful achievement. The rankings of all seven characteristics by each group, based on achievement score, are shown in Table 2.

Table 2

Comparison of Each Participant Group's Rankings of Achievement of Seven Judging Criteria

Survey Item	Rankings by Bilingual Generalists	Rankings by Regular Generalists	Rankings by Undecided Generalists
Creatively innovative	1	1	2
Creatively connected	2	2	1
Creatively enjoyable	5	3	3
Creatively challenging	3	6	6
Creatively integrated	6	5	5
Creatively equitable	4	7	7
Creative choices	7	4	4

Qualitative Analysis

The qualitative results obtained during this research study were analyzed to provide insight into the meaning of the quantitative findings discussed in the previous section using the grounded theory method of axial and selective coding (Strauss & Corbin, 1994) as described above. Based on this analysis it was determined that all three groups were able to point out similarities and differences between their own lessons and those created by their peers. The results are shown in Table 3, followed by a presentation and analysis of informative examples quoted from the participants' discussions of similarities and differences among the STEAM lessons and materials in terms of the four objectives extracted from participant responses.

Table 3

Each Group's Mentions of Top Two Achieved Criteria in "Similarities" Answers and Bottom Two Achieved Criteria in "Differences" Answers

Creativity-related Criteria Mentioned In	Creativity-related Criteria	Bilingual Generalist (n = 20)	Regular Generalist (n = 20)	Undecided Generalist (n = 20)
"Similarities" Answers	Creatively innovative	13 (65%)	18 (90%)	18 (90%)
	Creatively connected	15 (75%)	14 (70%)	9 (45%)
"Differences" Answers	Creatively challenging	13 (65%)	16 (80%)	18 (90%)
	Creative choices	9 (45%)	12 (60%)	5 (25%)

The two highest scoring objectives in terms of successful achievement were *creatively innovative* and *creatively connected*. In their responses to questions about similarities between their own presentations and those by the other teams, only 65% of BG participants discussed whether the lessons were creatively innovative, compared to 90% of RG and UG participants. On the other hand, only 45% of UG participants discussed whether the lessons were creatively connected, compared to 70% of RG participants and 75% of BG participants.

The two lowest scoring objectives in terms of successful achievement were *creatively challenging* and *creative choices*. In their responses to questions about differences between their own presentations and those by the other teams, only 65% of BG participants discussed whether the lessons were creatively challenging, compared to 80% of RG and 90% of UG participants. On the other hand, only 25% of UG participants discussed whether the lessons offered creative choices, compared to 45% of BG participants and 60% of RG participants.

Illustrative examples of responses from participants were selected to represent the qualitative results. The following is an example of a response from a BG participant that was coded for *creatively innovative*:

> One lesson that really stood up [*sic*] for me was the one where the students created a guitar using recyclable items but at the same time learning measurements and units. This lesson was very similar to ours because we used recyclable items to create a guitar as well, but in a different way. I thought this lesson was a very good idea to get the students engaged in learning measurements and units, especially when this can be something boring and dragging [*sic*] to learn, but by combining arts it becomes something fun.

This response suggests that creative innovation in a STEAM pedagogical approach has the potential to increase engagement during math lessons that may otherwise be perceived as boring.

The following is an example of a response from an RG participant that was coded for *creatively connected*:

> I noticed that other groups like my own group created activities that students would be able to create models and build things. I was glad that other groups included activities like these in their lesson plans because I believe that by including more hands on activities students will be involved in the learning process. One group focused on engineering different types of boats to see which ones float and which ones wouldn't. I thought that this activity was very well thought out and would be exciting to learn in the class. They were able to cover so many different topics in one activity: geometry, science, engineering, as well as giving their students the opportunity to be creative and create a ship that was all their own.

In this quote, the participant acknowledged the opportunities for creative pedagogical connections between multiple disciplines that can be provided by the STEAM pedagogical approach. The simple description of an activity as "engineering different types of boats to see which ones would float" dispelled for this participant any misconceptions that the STEAM pedagogical approach is patently overcomplicated or arduous.

The following is an example of a response from an RG participant that was coded for *creatively connected*:

> The activity that I found interesting was the group asked to the students [*sic*] to create their own guitar using the information covered in mathematics class and students then played with those instruments. The activity of the guitar not only allows students to show their creativity in the way they wanted to see their guitar, but also allows students to do a review on geometric figures. After showing their creativity in the design of the guitar and reviewing the different geometric figures, students also played their guitars that interesting [*sic*] but mostly fun for students.

The following is an example of a response from an RG participant that was coded for *creatively challenging*:

> Another difference between my group's lesson plan and other [*sic*] is that some lesson plans didn't build on each other. Each day's lesson was well thought out and informative but it didn't build on

> each other at the end of the week. To create a successful lesson plan and learning environment, its [*sic*] best if the students [*sic*] skills can be used and build on each other so they can remember the new information effectively.

These two quotes show the participants' recognition that a creatively challenging STEAM pedagogy engages students in learning. As another UG participant put it, "the students don't look at it as learning" but instead are so immersed in the experience that learning becomes indistinguishable from the creative aspect.

The following is an example of a response from an RG participant that was coded for *creative choices*:

> Although each team tried to incorporate a creative opportunity into each lesson plan, I believe some understood what exactly a creative opportunity is more than others. Yes, all the groups incorporated some type of art into the lesson plan, but sometimes this is not enough. I noticed that all the models would look exactly the same, rather than having many models that are similar but still show the individuality of each student. I believe that the lesson should have provided general guidelines so that the students understand the purpose of the lesson and know what is expected of them, but they still have room to make the decision as to what exactly the final product would look like.

In the above quote, the participant states that for STEAM pedagogy to engage students there must be sufficient opportunities for creative choices, but some of the STEAM lessons presented did not offer enough authentic opportunities for creative choices and therefore failed to "show the individuality of the student."

DISCUSSION

The main goal for this research study was to further detail the necessary supports for effectively implementing teacher preparation that encourages pedagogy connecting the standards-based curriculum with technology-supported opportunities for student creativity. For effective contextualized mathematics education to occur, teachers must have sufficient self-efficacy for teaching mathematics, both in terms of pedagogical self-efficacy and content knowledge self-efficacy (Bursal & Paznokas, 2006). Previous stud-

ies have used various approaches to implement and assess contextualized mathematics education designed to engage students in learning mathematics through connections to their real-life interests and ambitions (Cohen, Ducamp, Kjellstrom, & Tillman, 2012; Slykhuis et al., 2012).

Other related studies have aimed to help students who are disengaged from mathematics education to understand the connections between mathematics knowledge and their non-school life (Sherman & Wither, 2003; White & Garcia, 2010). The present study sought to narrow a gap in the empirical research about contextualized mathematics by examining any group differences in peer evaluation of the achievement of specific creativity-related objectives within STEAM lessons and materials developed by BG and RG participants, so that any dissimilarities in educational beliefs among these specialization groups might be strategically addressed. In particular, the present study was designed to examine differences between BG and RG participants to determine if there is sufficient evidence to justify proceeding to research on differentiating STEAM pedagogical preparation for BG and RG teachers.

The first research question asked: How did peer evaluations of creativity in STEAM lessons differ between BG and RG pre-service elementary teachers? The results showed that all groups (including BG, RG, and UG) of pre-service teacher participants gave the top two highest scores for achievement to the same creativity-related objectives: creatively innovative and creatively connected. All of the groups (including BG, RG, and UG) of pre-service teachers also gave the two lowest scores to the same creativity-related characteristics: creatively challenging and creative choices. In other words, the assessment of participants from all groups was that the STEAM presentations, taken together, were most effective at achieving the goals of including creative innovation and creative connection, and were least effective at achieving the goals of including creative challenges and creative choices. Although within the top two rankings, the bottom two rankings, and the three middle rankings, the groups differed in terms of the order in which they ranked the achievement of the creativity-related objectives, it was nonetheless concluded that the groups did not substantially differ regarding their peer evaluation rankings of the achievement of the creativity-related objectives.

The second research question asked: How did the perceptions of BG and RG pre-service elementary teachers regarding similarities and differences in STEAM lessons differ? The results showed that all groups (including BG, RG, and UG) of pre-service teacher participants were able to articulate similarities and differences between their own lessons and those

created by their peers, specifically: 65% of BG and 90% of RG participants discussed whether the lessons were creatively innovative; 75% of the BG and 70% of the RG participants discussed whether the lessons were creatively connected; 65% of the BG participants and 80% of the RG participants discussed whether the lessons were creatively challenging; and 45% of the BG and 60% of the RG participants discussed whether the lessons included creative choices. The widest differential between these amounts was 25% occurring between the BG and RG groups' discussions about creatively innovative similarities, with the second widest differential at 15% occurring between the BG and RG groups' discussion about creatively challenging and creative choices differences. Although these dissimilarities were not nil, nonetheless they were sufficiently small to warrant concluding the groups did not differ substantially regarding their perceptions of the similarities and differences in the STEAM lessons and materials. Therefore, based on the complementary understandings obtained from the quantitative and qualitative data analysis, it can be concluded that the BG and RG pre-service teacher participants did not differ substantially regarding either their peer evaluation rankings of the achievement of the creativity-related objectives, nor in their perceptions of the similarities and differences in the STEAM lessons. According to these findings, there appears to be no need currently to differentiate STEAM pedagogy preparation between BG and RG pre-service teachers.

Many of the same explanations for the results for RQ1 can be applied to the results for RQ2. Student teachers at the middle and high school levels often specialize (Jones-Kavalier & Flannigan, 2008), whereas student teachers at the elementary level are most often generalists (Midgley et al., 1995). The necessity of developing an instructional approach that applies to multiple subject areas results in a paradoxical situation where successful elementary teachers are often those whose pedagogical specialization is generalizing (Lajoie, 2003). Whereas both BG and RG participants were preparing to become primary school teachers and therefore pedagogical generalists, the BG teachers had self-selected the additional responsibility of specializing in delivering pedagogy in two languages along with the extra cognitive burdens such teaching entails (Spina, 2006). Thus whereas the RG teachers are expected to become pedagogical generalists, the BG teachers are expected to become both pedagogical generalists as well as pedagogical specialists. This dissimilarity in expectations might help explain the small, but nonetheless existent, differences encountered between the BG and RG teachers. In addition, elementary teachers that have a dual-language responsibility can sometimes hold inconsistent mathematics teaching self-efficacy attitudes

and student outcome expectations, as was shown in a study of Hispanic female pre-service elementary teachers that determined that even those participants with high mathematics teaching self-efficacy still displayed low expectations for their students' mathematics learning (Tillman, An, & Boren, 2013).

The findings from the data analysis pertain to the two problems addressed in the introduction, which discussed an increasing lack of creativity in STEM education coupled with an increasing lack of arts education. Within the context described, this study examined interdisciplinary STEAM pedagogy as a potential salve to these problems that might alleviate both synchronously. Specifically, the study addressed whether there were notable differences between BG and RG pre-service teachers that might necessitate differentiated instruction of STEAM pedagogy preparation, and determined based on the analysis of the quantitative and qualitative data collected that such differentiation was not warranted. These findings help address the problems of lack of arts education in school and lack of creativity in STEM education in that the overall similarities between BG and RG pre-service teachers in regards to STEAM pedagogy does not appear to necessitate differentiation between these groups, and therefore preparation can be synchronous.

Before proceeding to the conclusions, a few limitations to this research should be noted. First, almost all of the participating students were Latina females, so the quantitative findings might not be generalizable to non-Latina females or to male pre-service teachers. Further research confirming or refuting these findings for non-Latina and male populations are needed to address this sampling limitation. Second, this study involved a population that was sampled from a mid-sized urban geographic area on the US-Mexico border; therefore, generalizations of the quantitative findings may be limited to populations that reside within a similar geographical area. Further research confirming or refuting these findings for populations inhabiting other geographic regions are needed to address this sampling limitation. Additionally, the participants were combined into mixed groups containing BG, RG, and UG pre-service teachers and this might have impacted the results obtained, therefore a follow-up study in which the groups are separated might be warranted. Finally, the participating pre-service teachers were somewhat self-selected since they were all enrolled in the same courses from which study participants were recruited; accordingly, the sample was not truly random. Despite these limitations, the results have implications for the preparation of both BG and RG pre-service teachers in the use of interdisciplinary STEAM pedagogy—perhaps foremost of which is that the results help iden-

tify some of the challenges involved in integrating creativity-related objectives into STEM lessons and materials to create interdisciplinary STEAM pedagogy that contextualizes mathematics.

CONCLUSIONS

STEAM-themed lessons provide an avenue for introducing more creativity into the classroom, but the logistical and pedagogical obstacles are non-trivial. Multimedia technologies that enable students, as well as their teachers, to generate digital content can provide a mechanism for alleviating many of the obstacles that STEAM-themed lessons generate. Within this context, the present research study was conducted as part of an NSF-funded research project on improving the pedagogical content knowledge of pre-service and in-service primary school teachers by teaching STEM content though interdisciplinary approaches. This study analyzed peer evaluations of opportunities for student creativity within STEAM integrated lessons by pre-service elementary teachers and compared groups of participants based on their specialization (BG, RG, or UG). The results showed small differences in peer evaluations performed by the three groups in terms of their scores for achievement of seven creativity-related objectives, and when asked to describe similarities and differences between their own STEAM lessons and those of their peers.

The findings of this study have implications for addressing two prominent problems in K-12 education today. First, mathematics and science lessons are often taught in a manner that lacks opportunities for students to engage in creativity (Berry et al., 2010). Second, the arts and other creativity-focused subjects are allotted less time with fewer resources (White & Garcia, 2010). The present study examined the integration of STEM lessons with arts activities to create interdisciplinary STEAM education, with the goal of addressing both of these problems. The participating pre-service elementary teachers employed digital media production technologies to create STEAM lessons with accompanying multimedia, which provided a context for addressing the research questions.

The research was undertaken because although many of the BG and RG pre-service elementary teachers that participated in this study will likely become fully competent as primary mathematics educators, others are less equipped for many of the reasons already discussed. The unfortunate outcome is reflected in the body of research showing that traditional mathematics instructional methods are not serving all students equally (Hiebert &

Grouws, 2007), and that student attitudes towards STEM can be negatively impacted by poor pedagogical self-efficacy on behalf of teachers for mathematics and other STEM subjects (Gunderson et al., 2012).

Future studies within this NSF-funded project will continue to focus on improving pedagogical content knowledge among pre-service and in-service primary school teachers by teaching STEM content though interdisciplinary approaches that contextualize mathematics within authentically engaging settings. This study helped move that conversation forward by analyzing peer evaluations by pre-service elementary teachers of opportunities for student creativity within STEAM integrated lessons, and determining there were no substantial differences between the participating BG and RG pre-service teachers. Those interested in pursuing future research aligned with this line of inquiry are encouraged to focus on expanding the participant pool to include additional demographics including male pre-service teachers and non-Hispanic pre-service teachers.

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