

Development of Preservice Teachers'

INTERDISCIPLINARY

Pedagogical Content Knowledge:

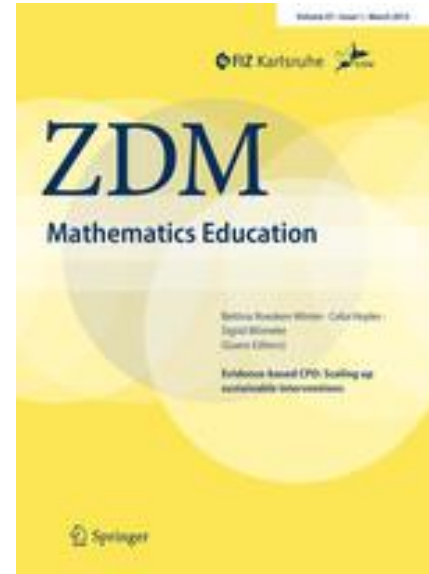
A Preliminary Exploration of STEM Integration

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An, S. A., Tillman, Zhang, M., D., Robertson, W., & Tinajero, J. (2016). Hispanic preservice teachers' peer evaluations of interdisciplinary curriculum development: A self-referenced comparison between monolingual generalists and bilingual generalists. *Journal of Hispanic Higher Education, 15*(4) 291-309.



An, S. A. (2017). Preservice teachers' knowledge of interdisciplinary pedagogy: The case of elementary mathematics-science integrated lessons. *ZDM -The International Journal on Mathematics Education, 49*(2), 237-248.

U.S. Model VS China Model

Elementary teachers in many Asian countries are prepared as specialists in individual school subject

they are math teachers, language arts teachers.

Elementary teachers in the United States are prepared as generalists

they responsible for teaching multiple school subjects, including language arts, mathematics, science, and social studies.

U.S. Model VS China Model

Teachers teach the same class of students for

Subject A

Subject B

Subject C

Subject D

I am a fourth grade teacher
for different group of students each year



Teachers teach individual school subjects for

Class 1

Class 2

Class 3

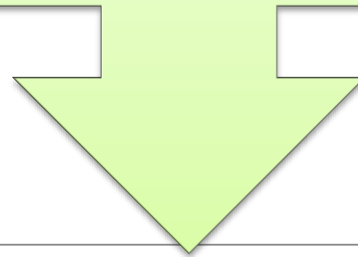
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I am a elementary math teacher
for the same students from grade 1 to 6



Teachers' Knowledge

Teachers' pedagogical ability has been repeatedly identified as the essential factor for impacting students' learning outcomes and motivational levels (Baumert et al. 2010; Hattie 2009). Highly qualified teachers, especially mathematics teachers, are—by definition—those teachers that have substantial knowledge about varying teaching approaches relevant to their subject areas.



This general knowledge base includes the following:

classroom
management

lesson design and
implementation

understanding of the
mathematics content

methods of engaging
students to access
these mathematical
ideas

Issues of Teacher Education

- Teacher education programs in the United States focus on preparing preservice elementary school teachers to instruct multiple school subjects, with an emphasis on generalizable pedagogy rather than advanced or domain-specific pedagogical content knowledge (Anderson & Clark, 2012).

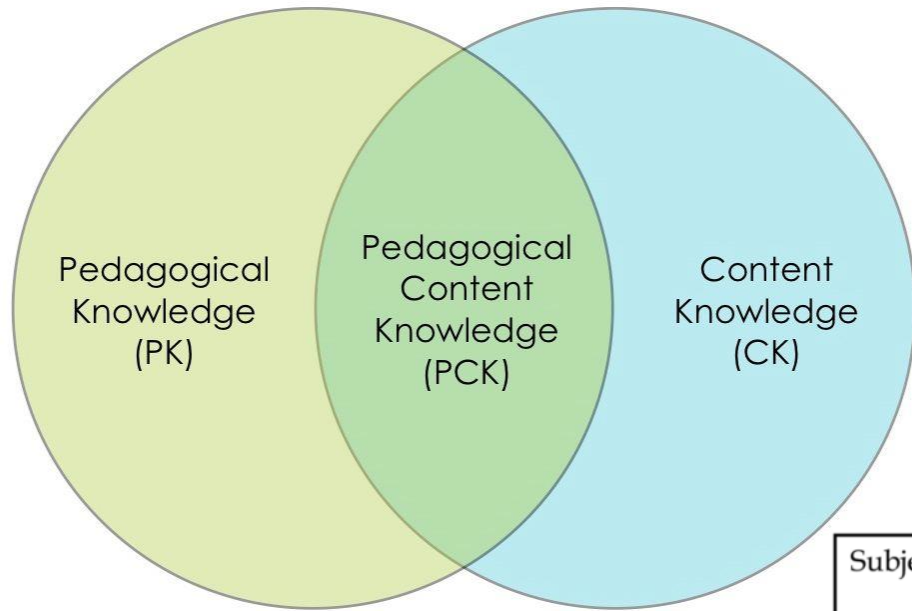
Math
Methods

Science
Methods

Social Studies
Methods

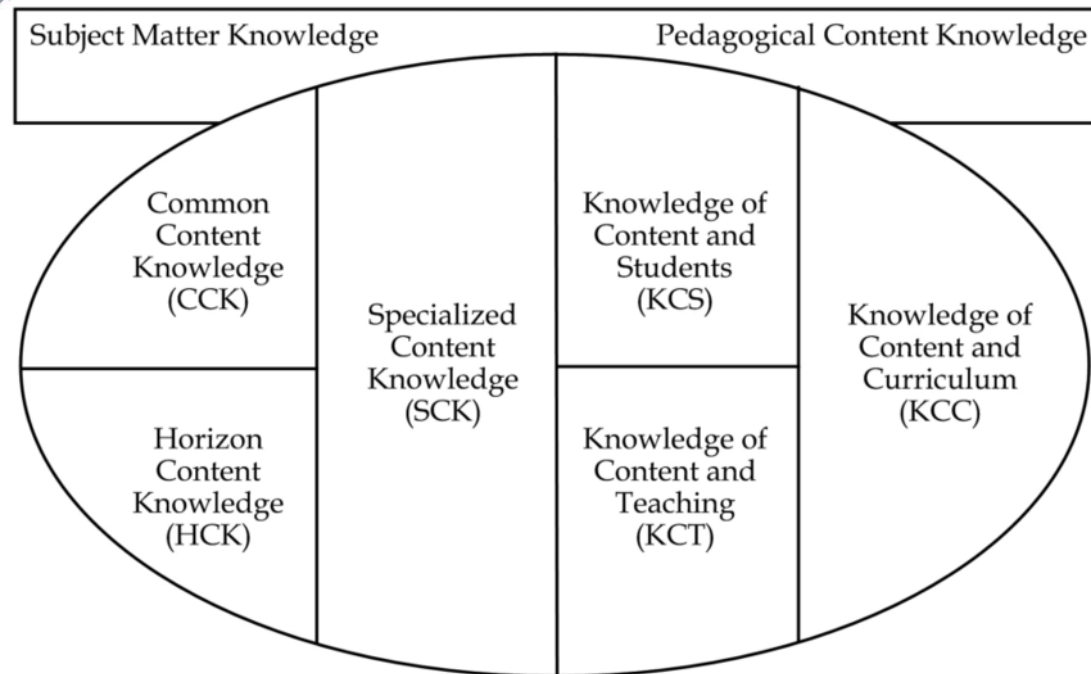
Literacy
Methods

PCK and Variations



Shulman (1986)

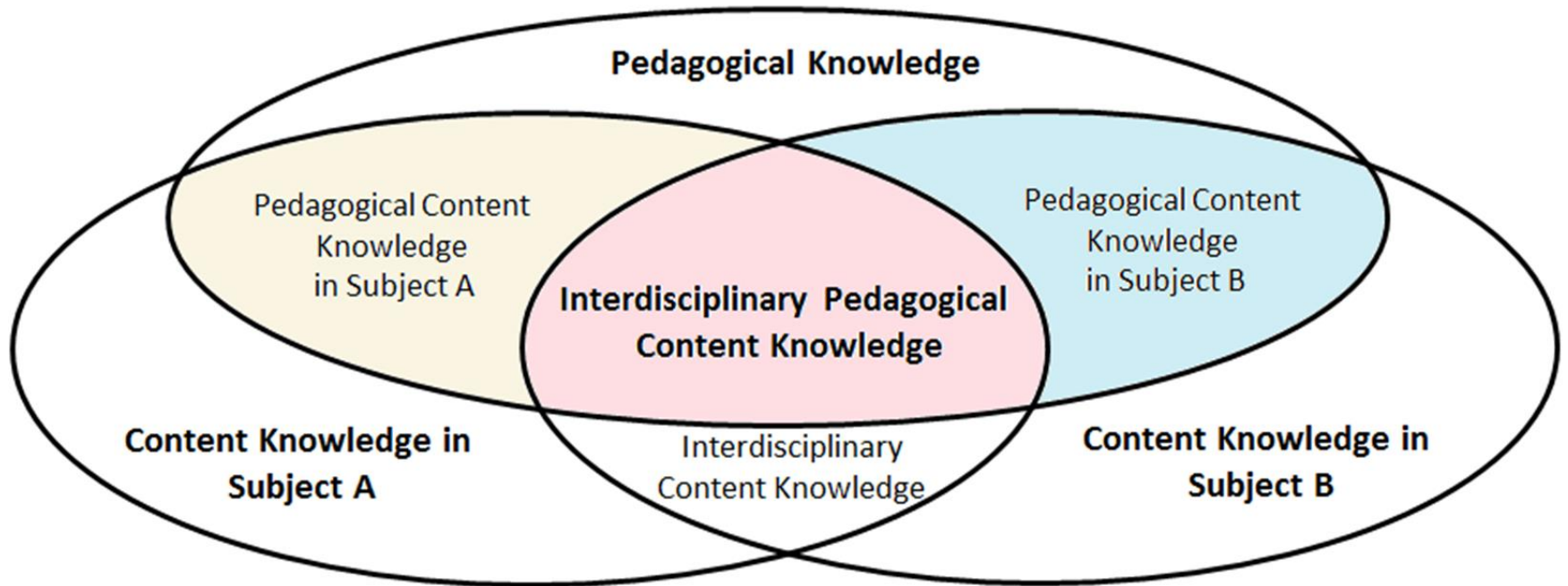
Ball et al. (2008)



Previous Research

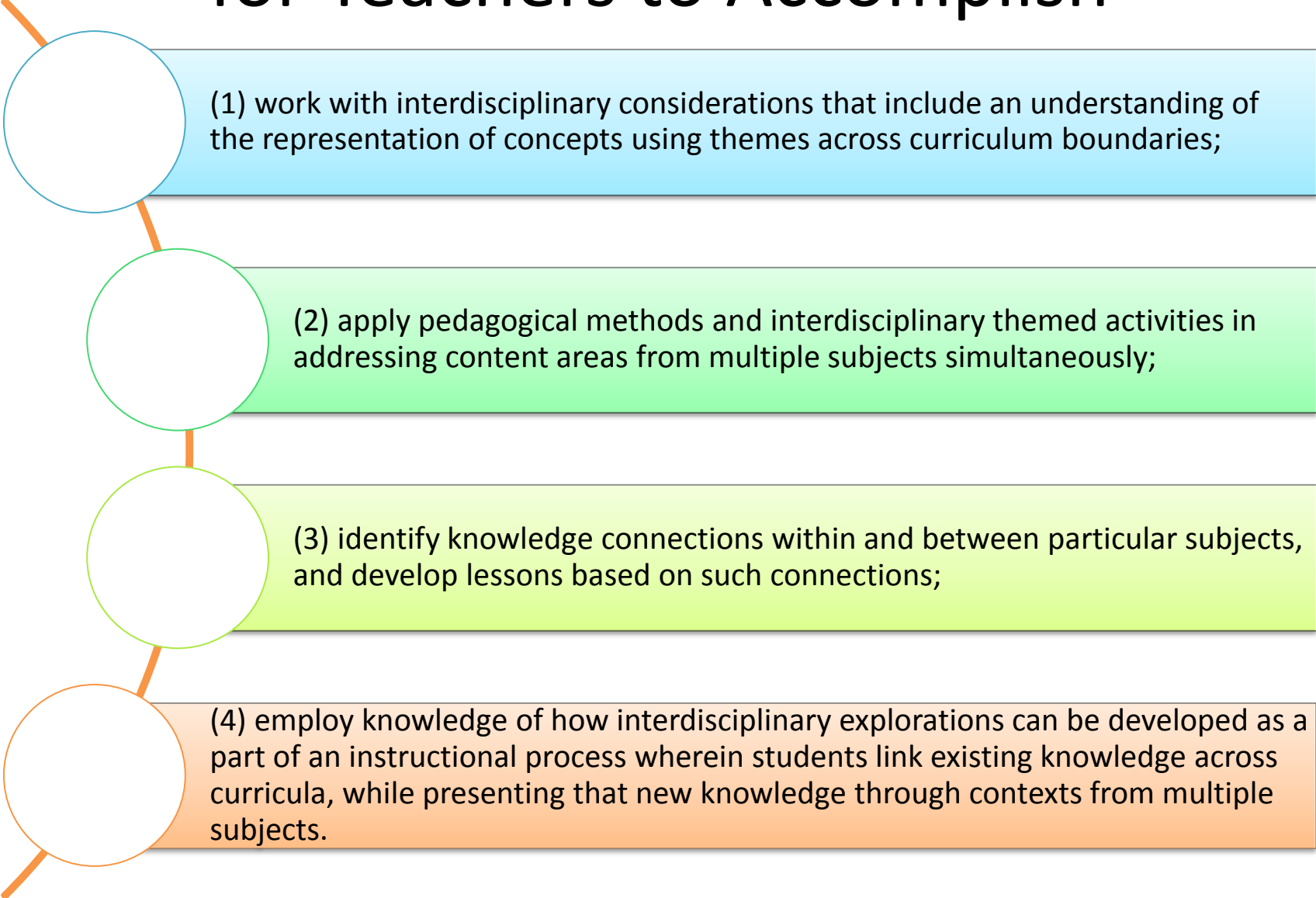
- Our previous research has indicated that the development of teachers' understanding of teaching, content, curriculum, pedagogy, and students, especially in the subject of mathematics, are **all needed to transverse the subject area boundaries that divide the individual disciplines**, and this requires development of teachers' Interdisciplinary PCK (An and Tillman 2014; An, Tillman, Shaheen, and Boren 2014; An, Tillman, and Paez 2015)

IPCK



An (2017)

IPCK is the Specific Capacity for Teachers to Accomplish



(1) work with interdisciplinary considerations that include an understanding of the representation of concepts using themes across curriculum boundaries;

(2) apply pedagogical methods and interdisciplinary themed activities in addressing content areas from multiple subjects simultaneously;

(3) identify knowledge connections within and between particular subjects, and develop lessons based on such connections;

(4) employ knowledge of how interdisciplinary explorations can be developed as a part of an instructional process wherein students link existing knowledge across curricula, while presenting that new knowledge through contexts from multiple subjects.

Research Questions

- (1) What differences were there between the monolingual generalists and the bilingual generalists in regard to judging their peers' interdisciplinary instructional designs according to self-referenced criterion?
- (2) How did elementary preservice teachers' interdisciplinary pedagogy change as a result of participating in exemplary interdisciplinary mathematics activities?

Methods

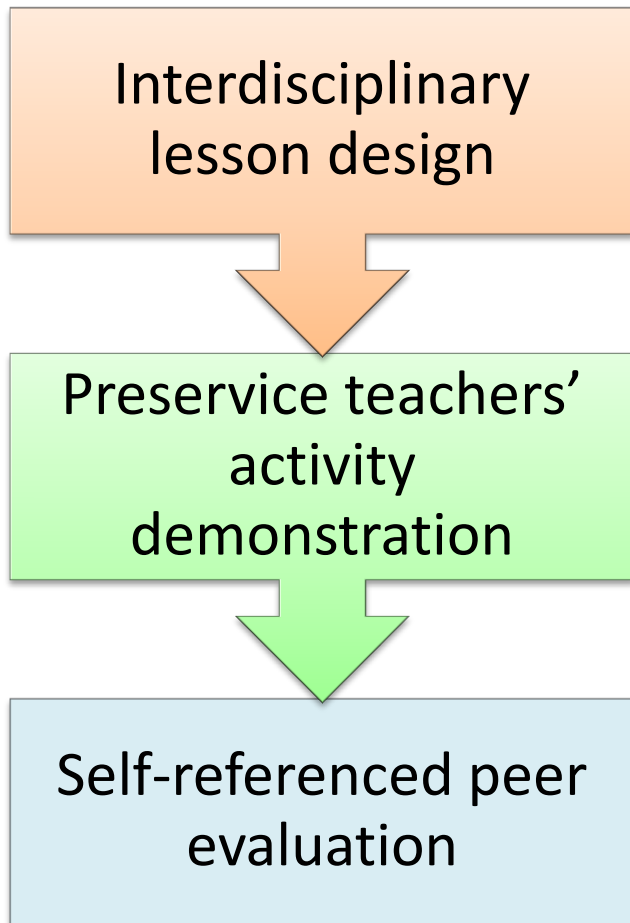
The aggregate participants in the larger research projects were 342 preservice teachers from six cohorts who were enrolled in either the elementary generalist certificate program, the elementary bilingual generalist certificate program, or the special education certificate program, from spring 2013 to fall 2015.

For study 1, data were collected from 36 preservice teachers in summer 2014

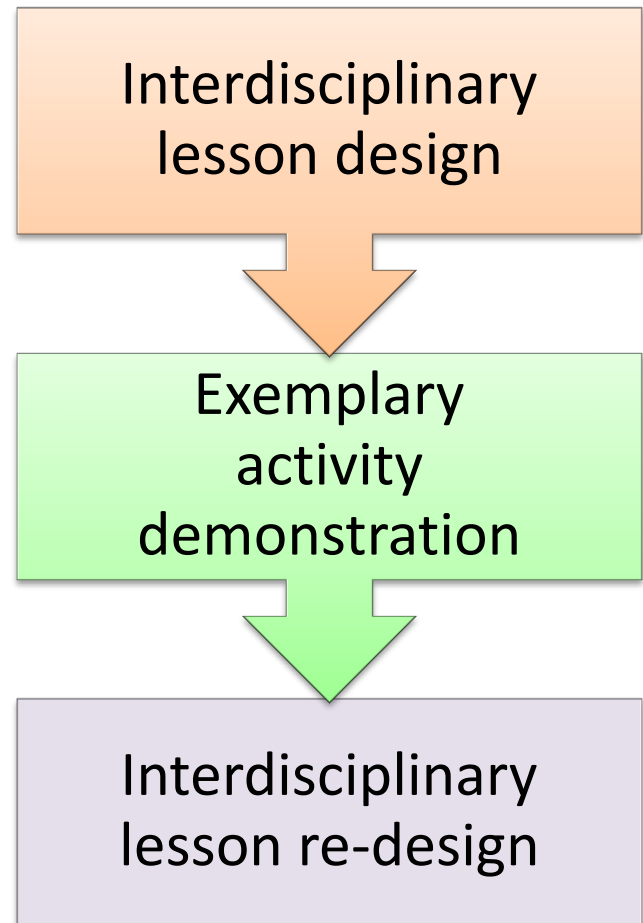
For study 2, data were collected from 28 preservice teachers in fall 2015

General Procedure

Study 1



Study 2



Study 1

What is Self-referenced Evaluation?

Why Use Self-referenced Evaluation?

(a) the lessons are **far poorer** in quality than your own lessons,

(b) the lessons are **poorer** in quality than your own lessons,

(c) The lessons are **the same** in quality as your own lessons,

(d) the lessons are **better** in quality than your own lessons, and

(e) the lessons are **far better** in quality than your own lessons.

Process

In total, 36 preservice teacher participants each performed a peer evaluation of the 35 instructional designs that were presented (one participant performed the peer evaluations but did not complete the instructional design assignment).

- **In total, 1,260 peer-evaluation surveys were collected.**

After the collection of the peer evaluations discussed in the previous paragraph was completed, the 36 preservice teacher participants were invited to partake in the follow-up qualitative inquiry processes.

- **In total, 95 pieces of individual reflection were collected from the monolingual generalists, and 85 pieces of individual reflection were collected from the bilingual generalists.**

Process

The open-response inquiry prompts asked participants to address the following topics based on their peer-evaluation experiences:

Describe the **similarities/differences** between your lessons and your classmates' lessons in terms of opportunities for students to engage with and understand mathematics,

Provide reasons with examples for your judgment of why some of your classmates' lessons are **poorer/better** than yours,

What is your view about teaching mathematics through interdisciplinary strategies?

Self-Referenced Peer-Evaluation Scores

Evaluation Aspects	Groups	Mean (SD)	p-value (t-value)	Effect Size (Cohen's d)
The lessons creatively demonstrated different ways of teaching math	MG (n=665)	2.94 (0.79)	<0.001 (4.994)	0.29
	BG (n=595)	3.17 (0.82)		
The lessons can effectively engage and motivate students to learn math.	MG (n=665)	2.91 (0.72)	<0.001 (5.189)	0.29
	BG (n=595)	3.12 (0.72)		
The lessons can help students to understand math through alternative ways.	MG (n=665)	2.89 (0.75)	<0.001 (6.052)	0.35
	BG (n=595)	3.15 (0.74)		
There are logical reasons for the order of the lessons, and the five lessons had coherent themes	MG (n=665)	2.88 (0.60)	<0.001 (6.076)	0.35
	BG (n=595)	3.10 (0.67)		
The lessons can support bilingual students learning mathematics.	MG (n=665)	2.86 (0.56)	<0.001 (7.302)	0.41
	BG (n=595)	3.12 (0.70)		

Evaluation Foci for Interdisciplinary-Themed Mathematics Instructional Design

General Criteria	Specified Evaluation Criteria	MG		BG	
		Response Counts (Rates)			
Pedagogical connections	Target math topics are meaningfully connected with other math concepts	25		8	
	Target math topics are meaningfully connected with non-math concepts	12		23	
	Target math topics are contextualized through multiple themes	6	(77%)	14	(71%)
	Target math topics are conceptualized through multiple approaches	13		2	
	Allows students to apply target math topics in real world scenarios	18		5	
Curriculum structure and lesson foci	The lesson design is appropriate for students' age/grade	12		14	
	The lessons match curriculum standards	24		6	
	Activities built on each other from start to finish in each lesson	17	(112%)	8	(87%)
	There are logical reasons for the order of the lessons	28		22	
	The lessons have coherent interdisciplinary themes	9		19	
	The lessons have progressive mathematics foci	16		5	
Differentiated instruction	Special activities were prepared for bilingual/ELL students	5		38	
	Special activities were prepared for gifted students	12		9	
	The lesson utilized multiple instructional approaches (e.g. group discussion)	13	(46%)	7	(80%)
	Activities match students' cultural backgrounds	0		12	
	Uses different methods to assess student understanding	14		2	
Opportunities to explore mathematics	Students have opportunities for self-directed learning	16		7	
	Students have opportunities to reflect on their own learning	12		2	
	The lesson provided various non-drill activities	22	(85%)	17	(36%)
	Students can choose their own way to solve math problems	18		2	
	The lesson provide challenges that activate students' higher-order thinking	13		3	
Total Response Counts (Rates)		305		225	
		(321%)		(268%)	

Quantitative Findings

- The results obtained from this study provide evidence that bilingual generalists, when evaluating their classmates' instructional designs, tend to give higher scores than their peers that are monolingual generalists.
- This indicates that the participating monolingual generalists had higher expectations than the bilingual generalists in all five evaluation aspects.

Quantitative Findings

- These prominent differences in overall peer-evaluation results reflect the apparent fact that the bilingual generalists had lower self-efficacy in their interdisciplinary-themed mathematics instructional designs than their monolingual generalists peers.
- This difference might be explained by recognizing that the bilingual generalists' self-efficacy toward mathematics education occurs within the context of dual language communication requiring decoding of mathematical symbols and abstract concepts through linguistic approaches that involve language switching (Cowan & Albers, 2006).

Qualitative Findings

- Compared with the monolingual generalists, when designing and implementing interdisciplinary-themed mathematics lessons, the bilingual generalists appear to place higher emphasis upon affective aspects of the lessons instead of cognitive considerations.
 - On average, each monolingual generalist reported using 3.2 specific evaluation criteria, while each bilingual generalist reported using 2.7 specific criteria in their peer-evaluation process.
 - The number of evaluation criteria indirectly affected the scores that preservice teachers gave for their peers, as having more foci for evaluation resulted in correspondingly more identification of limitations.

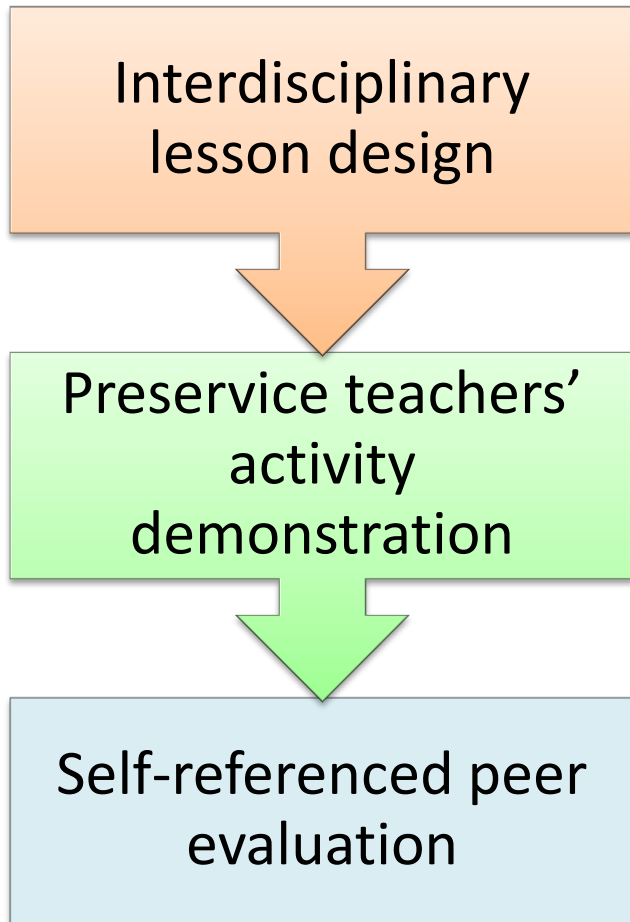
Discussion

- The differences that were noted in this study between the monolingual generalists and bilingual generalists should **NOT** be misinterpreted as indicators that one group of teachers is better than the other group in their instructional design capacities.
- **Evidence indicated that the two groups of teachers were dissimilar in several ways during the peer evaluations in how they created rubrics and how they developed their peer-evaluation rationale.**
- The differences between bilingual generalists and monolingual generalists while designing and evaluating STEM lessons displayed within the current study, as well as several prior studies (e.g., Cooper & Schleser, 2006; Saalbach et al., 2013), **illustrate the need for providing differentiated teacher preparation activities** for preservice bilingual teachers based on their unique pedagogical, cognitive, and linguistic requirements.

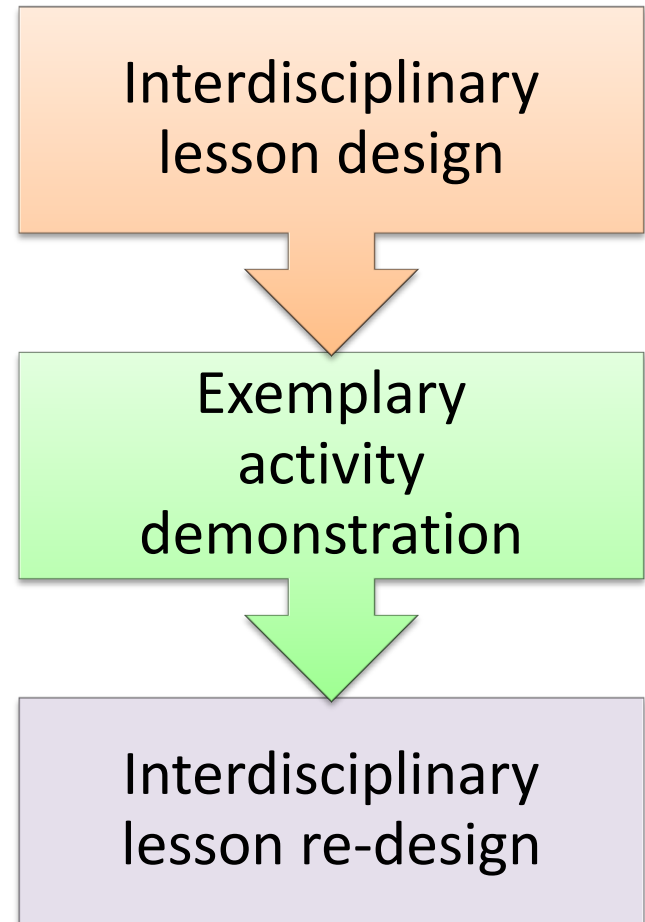
Study 2

General Procedure

Study 1



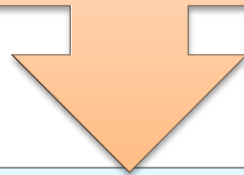
Study 2



General Procedure

Data Collection		Intervention	Data Collection	
Week 1	Week 2	Week 3-11	Week 12	Week 13
Pre-survey Part I	Pre-survey Part II	Exemplary Contextualized Mathematics Teaching Strategy Demonstration, Strategy Design and Peer Evaluation	Post-survey Part I	Post-survey Part II

The intervention was constituted of a series of eight sets of exemplary interdisciplinary activities that were selected from 509 lesson plans designed by preservice teachers



A total of 24 activities were selected to be presented to the participants in the current study, and these activities were selected based on the comprehensive results of

self-referenced peer evaluation
(An et al., 2015)

group-referenced peer
evaluation (Tillman et al., 2015)

teacher educators' evaluation
(An & Tillman, 2014)

Physics Themed Mathematics Teaching Strategies in Pre-survey

Quantify what colors absorb the most heat by place different colored papers outside with thermometers

Put different type of liquids (e.g. rubbing alcohol, vegetable oil, milk, dish soap, maple syrup) into a clear container and observe the pattern of density from layers

Drop different items (e.g. basketball and tennis ball) at the fixed point and observe whether they reach the floor at the same time and measure the falling time

Put different food items (e.g. chocolate, butter, and cheese) into a heated cupcake pan and create a graph to record the time of melting from solid to liquid

Chemistry Themed Mathematics Teaching Strategies in Pre-survey

Find atomic mass or neutron of an element by solving the equation with missing variables

Introduce units and tools for measure small amount of chemicals including solid, liquid and gas

Use pH Test Strips to test a variety of liquids and compare pH levels and determine the acid or base

Measure the differences of spin speed between raw eggs and boiled eggs to explore the chimerical change of molecular structures

Biology Themed Mathematics Teaching Strategies in Pre-survey

Plant beans in a clear cup with soil and observe how many days it took for the bean to sprout and to days it took for the stem to come of the soil

Plant beans with different nutation and conditions, control variables and compare the growth by measuring the height of the plants

Explore human body by counting the number of bones and teeth, labeling the nerve system and calculate the percentage of body fat among different people

Have students run around and do physical activities while measuring their heart rate, and creating charts of the difference between heart rates

Any patterns?

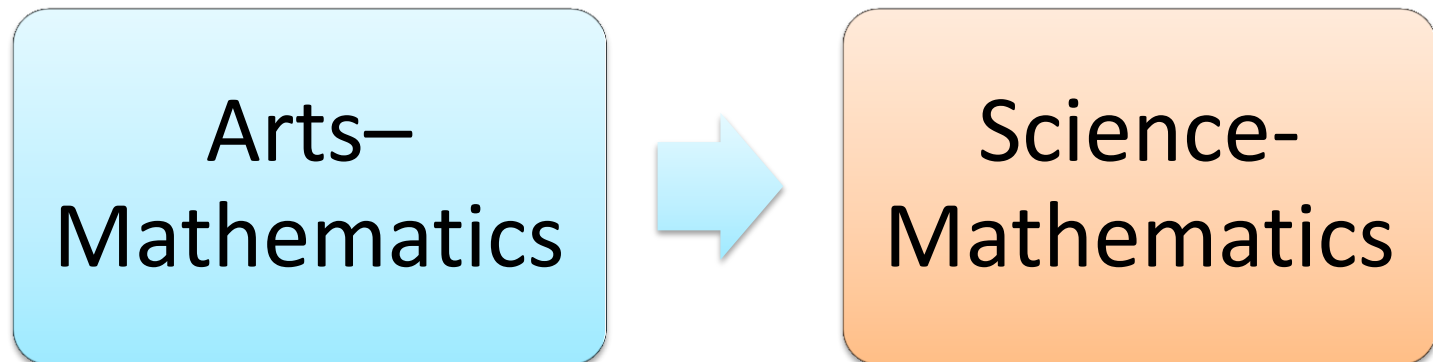
- Most pedagogical designs in the pre-survey are using science activities as a means for conducting basic measurement

Intervention

Pedagogy Transfer

This study examines the potential for an integrated mathematics–arts teaching approach as a bridge to enable preservice teachers’ pedagogy transfer from the arts to non-arts content (such as science).

- We aimed to develop preservice teachers’ interdisciplinary teaching expertise within an easier domain, namely ***arts–mathematics***, before transitioning to a more difficult domain, namely ***science–mathematics***, in order to provide essential scaffolding.



Physics Themed Mathematics Teaching Strategies in Post-survey

Create levers or push and pull systems and then compare the efficiency through experiments

Build ramps for toy cars with different heights and slope, and then explore the variables that impact the speed

Build bridges with popsicle sticks in different shapes and explore the most support to provide from collapsing

Explore the concept of dry friction by rolling balls with different sizes and materials from the same point and compare the traveling distance

Chemistry Themed Mathematics Teaching Strategies in Post-survey

Mix certain quantities of substance together and then determine how the reaction can change by manipulating if the amount of items

Explore 3-D geometry through the creation of molecules in each compound by using jelly beans and toothpicks

Experiment with different materials to find out which mixture makes the best crystals, then explore shapes and symmetry

Explore algebraic patterns in about atoms and determining how many electrons one atom has to lose or share during bonding processes

Biology Themed Mathematics Teaching Strategies in Post-survey

Identify different ant farms and observe how the ants work to make their colony, and collect data on the different groups to investigate the optimal number of ants to create a colony

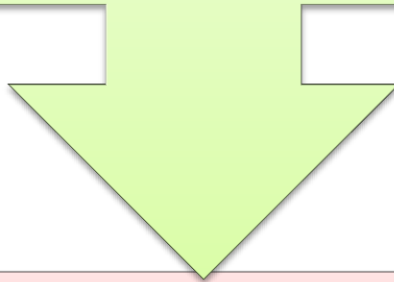
Identify patterns in life cycle across different insects and plants by numbering the sequence stages, and investigate mathematical structure in different type of food chains

Have students gather up leaves and sort the leaves out in based on different ways of categories and construct statistical graphs and Venn diagram to represent their findings

Find the differences in height and weight of different kinds of animals and explore the relationship between the size of the animal versus the amount of food and water they need to consume per day

In the Post-Surveys

Rather than merely using science related tasks as warm-up practice during mathematics lessons such as in the pre-surveys, during the post-surveys a range of pedagogical approaches supporting mathematics content areas, such as algebra, geometry, data analysis and probability, were reported.



Such as

Exploring ratios connecting physics and algebra;

Visualizing symmetry, connecting chemistry and transformations in geometry;

Conducting experiments with heredity that demonstrate connections between biology and probability.

Discussion

- Researchers across the globe, in both centralized educational systems (e.g., Kim and Bolger 2016; Lam et al. 2013; Saçkes et al. 2012) and de-centralized educational systems (Venville et al. 2012; Samson 2014; Cady and Rearden 2007) have identified, implemented, and assessed various integrated methods for teaching mathematics and science content.
- However, there has not been a definitive answer as to how best to improve preservice teachers' instructional design for interdisciplinary mathematics–science pedagogy.

Discussion

- The current study attempted to help fill this research gap by examining potential techniques and prospects for facilitating preservice teachers, development of their own knowledge for supporting science-themed mathematics pedagogy, **by first employing a less intimidating form of interdisciplinary mathematics education, namely arts-themed mathematics education.**

Discussion

- Traditional teacher education programs are customarily organized to emphasize mono-disciplinary instructional methods, which highlight distinct disciplinary boundaries (Labaree, 2008).
 - Such teacher education programs that are rooted in **separating** disciplines into discrete silos have **failed** to offer relevant and engaging pedagogical practices for preservice teachers to develop the style of pedagogy needed to reach out successfully to the numerous demographics of historically underserved students.

Math
Methods

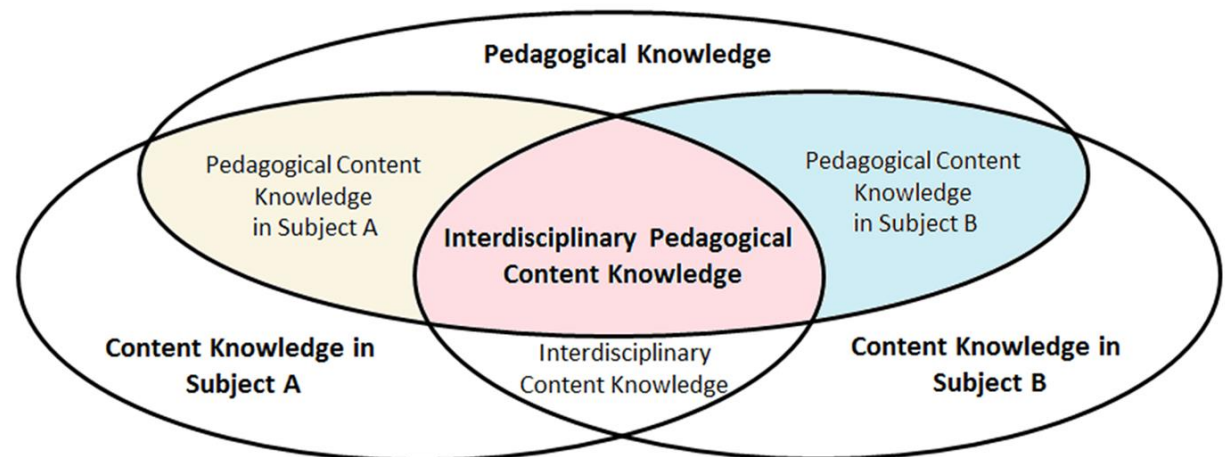
Science
Methods

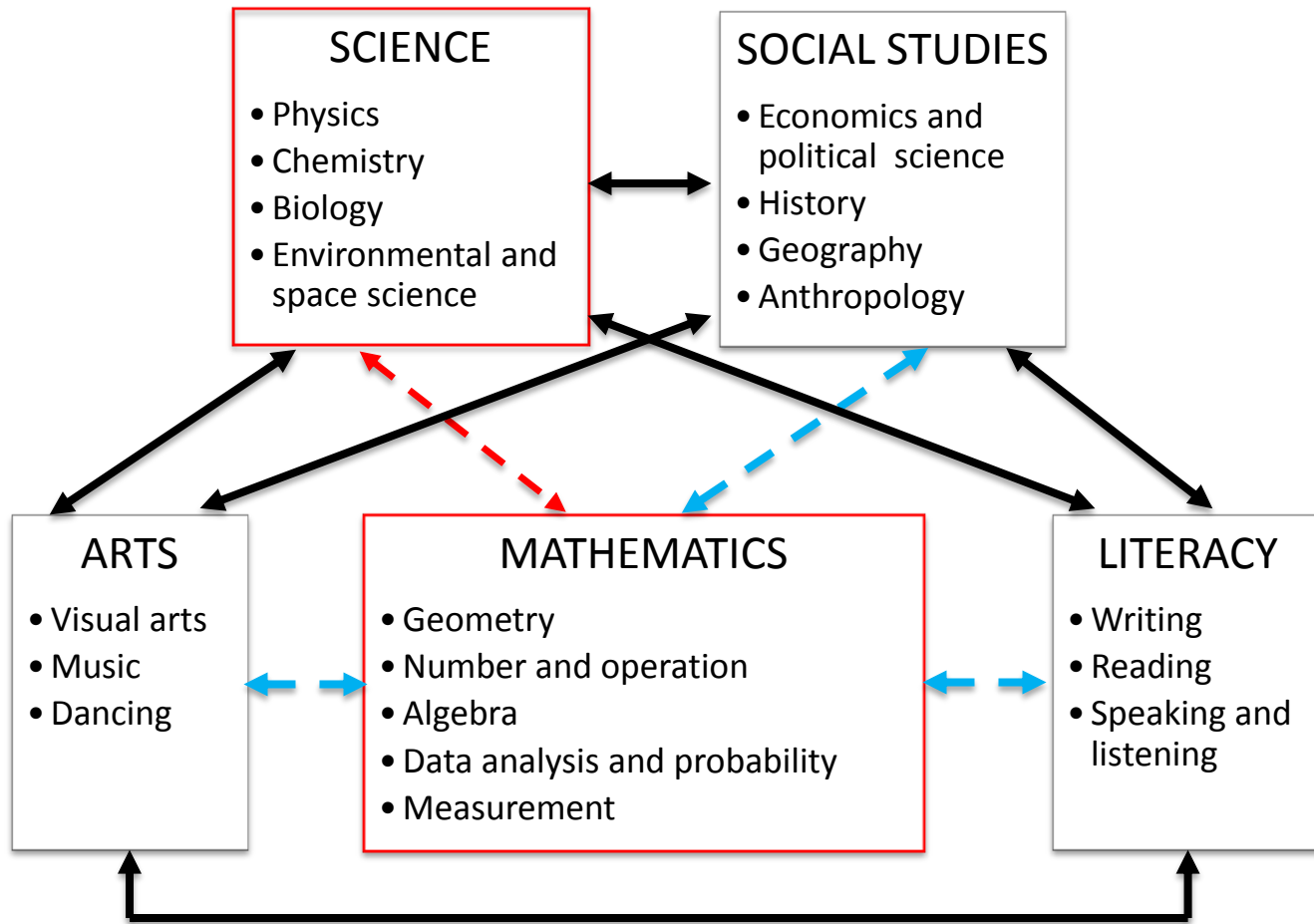
Social Studies
Methods

Literacy
Methods

Addressing the Development of IPCK

- Competent teachers should be able to identify, choose and adapt interdisciplinary exploration opportunities which enable structured tasks wherein students apply high-level thinking processes (e.g., analysis, synthesis, and evaluation) during their daily lessons (Drake and Burns 2004).
- This purpose can be accomplished by having teacher educators prepare future teachers via **interdisciplinary orientations** that cross different subject areas and thereby help students achieve authentic understanding and interest in the subjects taught (Knoblauch and Hoy 2008).





- The findings from this study invite additional empirical investigation of how to improve teacher education programs by **adding more interdisciplinary components**.
- There is hence an opportunity for research examining many such potentially creative contexts, such as those that integrate science, social studies, the arts, and language arts, into the development of mathematics preservice teachers' pedagogical practices.

Questions?

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