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ICRSME

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A Reflection On The First Five Years Of EJRSME

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A Reflection on the First Five Years of *EJRSME*

In March of 2019, we took over the executive directorship of the International Consortium for Research in Science & Mathematics Education (ICRSME). Several months later, Dr. Molly Weinburgh and Dr. Michael Kamen, former editors of the *Electronic Journal of Science Education* (*EJSE*), proposed that *EJSE* become the flagship journal of ICRSME and its scope be expanded to include mathematics education. From that suggestion, *EJSE* became the *Electronic Journal for Research in Science & Mathematics Education* (*EJRSME*) and for the last five years, we have been the editors of *EJRSME*. In this, our last editorial, we reflect on our five-year tenure as editors and express our gratitude to the community of colleagues who have contributed to the evolution of *EJRSME*.

ICRSME and *EJRSME*

The mission of ICRSME centers on international collaboration in science and mathematics education:

> The mission of the International Consortium for Research in Science and Mathematics Education (ICRSME) is the advancement of science and mathematics education in the participating countries. This mission is based on the premise that all peoples can benefit from the knowledge and experiences of their local, national, and international colleagues. ICRSME focuses on programs for development, innovation initiatives, and shared resource opportunities. (ICRSME, 2024, para. 1)

With ICRSME taking on the publication of *EJRSME*, the purview of the journal changed to reflect the mission of ICRSME:

> *EJRSME* publishes manuscripts relating to issues in science/mathematics education and science/mathematics teacher education from early childhood through the university level including informal science and environmental education. *EJRSME* reviews original science and mathematics education manuscripts that report meaningful research, present research methodology, develop theory, and explore new perspectives and teaching strategies. (EJRSME, 2024, para. 1)

In our conversation with Dr. Donna Berlin, one of the founders and long-time organizer of ICRSME, she succinctly described the mission of ICRSME: "If I had to pick two words, it would be collaboration and sharing. That's what was the initial mission and goals" (Quebec Fuentes & Bloom, 2021b, p. 5). This foundation of collaboration and sharing has been extended to the work of *EJRSME* and is grounded in the idea of *communities of practice* (Quebec Fuentes & Bloom, 2021a).

Wenger et al. (2002) define communities of practice as "groups of people who share a concern, set of problems, or passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis" (p. 4). Wenger et al. (2002) elaborate further on the critical components of communities of practice: "a domain of knowledge, which defines a set of issues; a community of people who care about this domain; and the shared practice that they are developing to be effective on their domain" (p. 27). Under the auspices of ICRSME, the multiple stakeholders, who are involved with the publication of *EJRSME*, form a community of practice. Specifically, they form a community of people who are passionate about the domains of science, mathematics, and STEM education and who contribute to the publication of research, practitioner, and theoretical pieces that support the advancement of the aforementioned fields.

In communities of practice, "learning is viewed as distributed among many participants within the community in which people with diverse expertise (i.e., experts, novices, and those in between) are transformed through their own actions and those of other participants" (Buysee et al., 2003, p. 266). Dr. Berlin's description of the efforts during ICRSME Consultations reflects this view of learning:

> *We were collaborating on research; we wanted to share the research. With the Consultations, we were able to share it to a wider audience. We were able to get feedback from other people as well and see what other people were doing related to what we were doing. Because it was research-based, it was all of benefit, really beneficial to all the people that were participating … college and university [faculty], … K-12 classroom teachers, … graduate students.* (Quebec Fuentes & Bloom, 2021b, p. 5)

EJRSME is another mechanism for learning in and enhancing the fields of science, mathematics, and STEM education. The various stakeholders contributing to the publication of *EJRSME* (e.g., authors, reviewers, Associate Editors, Copyeditors, and Editors) learn through and with one another as articles progress through the revision process. Such a process requires trust and respect as the *EJRSME* stakeholders communicate openly and critically (Palinscar et al., 1998; Wenger et al., 2002). Dr. Donna Berlin further explained the nature of interactions between ICRSME friends:

> *The special part of it, to me and I think for many other people, was the collegial and supportive relationships. Everybody was there to help everybody else to get tenure, to get things published, to do better research, do better writing … that's the unique part of [ICRSME], everybody was really there to support one another.* (Quebec Fuentes & Bloom, 2021b, pp. 3-4).

Similarly, we view the work of *EJRSME* through a *mentor mindset*, clearly articulating our mission and goals, valuing the work of authors and those who provide feedback to authors, and maintaining rigorous standards (Yeager, 2024). The support of our colleagues in their academic endeavors is achieved through trust and respect and is a hallmark of ICRSME and, in turn, of *EJRSME* as well.

Evolution of *EJRSME*

The publication of *EJRSME* involves a community of volunteers. When we took on the editorship of the journal, we built this community and streamlined the responsibilities of these volunteers. First, the journal has multiple editors, at least one responsible for all science education submissions and at least one responsible for all mathematics education submissions. Each editor works with a team of Associate Editors who are responsible for facilitating the review process for individual articles, including assigning each article to at least two reviewers. For a detailed account of the publication process, see Bloom and Quebec Fuentes (2023). The change in scope and editorial structure required us to build and maintain teams of Associate Editors (with three-year terms) with expertise in science education or mathematics education. Early on in our tenure as editors, the COVID-19 pandemic occurred, causing difficulties in obtaining reviewers for articles in a timely manner (Flaherty, 2022). In response to this issue, we recently started to build an Editorial Review Board (ERB). Members of the ERB commit to regularly reviewing articles for *EJRSME* over a three-year period. These efforts continue.

In addition to the changes in journal focus, editorial team, and name, *EJRSME* was also transformed visually to align with ICRSME branding. In 2019, a graphic design student at Dallas Baptist University (DBU), Alex Stephens, worked with us to develop a prototype of the current ICRSME branding. Later, Dr. Jonathan Crocker, then a doctoral student at Texas Christian University (TCU), modified this early design to incorporate the current blue and green color scheme. The *C* in the ICRSME logo represents a desk globe and its stand with the globe highlighting the area of the world in which ICRSME Consultations are held (left side of Figure 1). The new partner logo for *EJRSME* incorporates both the color scheme and iconic *desk globe letter C* (right side of Figure 1).

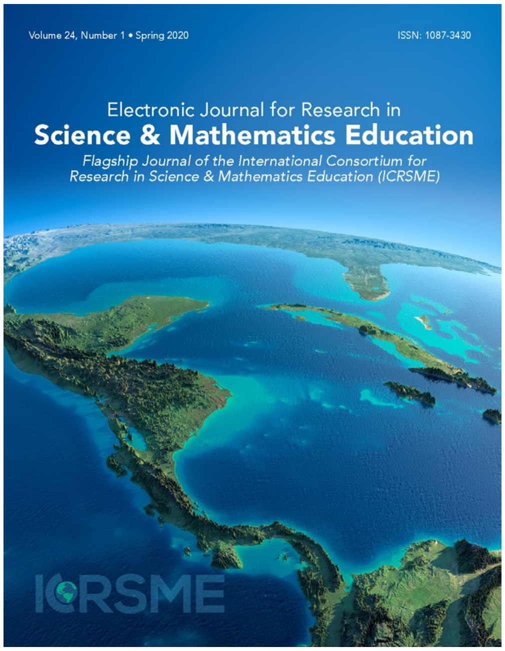
Figure 1

ICRSME and EJRSME Logos

The journal itself also received a facelift. The cover of the journal was redesigned by Dr. Dusty Crocker, Design Professor of Professional Practice at TCU, to reflect the new branding of ICRSME and *EJRSME*, emphasizing their connection (left side of Figure 2). Again, the background image of Earth focuses on the geographic region where ICRSME Consultations are conducted with Panama, the site of the first Consultation held under our directorship, prominently displayed. The interior of the journal was also reformatted with a new article template that includes the ICRSME logo and fresh font and color-scheme (right side of Figure 2). To complete the coordination between ICRSME and *EJRSME*, we created the ICRSME website and revised the *EJRSME* website, linking the two.

Figure 2

EJRSME Cover and New Article Template



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ICRSME
International Consortium for Research in
Science & Mathematics Education

Structuring Integrated STEM Education Professional Development: Challenges Revealed and Insights Gained from a Cross-Case Synthesis

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University of Kentucky

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Bellarmine University

Christopher R. Rakes
University of Maryland Baltimore County

Robert N. Ronau
Johns Hopkins University

Jon Saderholm
Berea College

ABSTRACT

Integrated STEM PD has challenges unique from those normally faced by single-discipline PD. The purpose of this validation study was to examine the effectiveness of the PrimeD framework to guide and improve integrated STEM professional development (PD). Three federally funded PD programs in the United States, focused at different grade bands K-12, were examined using a qualitative cross-case synthesis approach to study the structure of each PD program as well as the benefits and limitations of PrimeD. Findings revealed that PrimeD offered structure and flexibility that guided leaders to be intentional, notice program improvement opportunities, and embrace collaboration and transparency. The framework holds much promise for integrating a wide array of recommendations for effective PD in the field of integrated STEM PD. Even so, the normal struggles and challenges of a STEM PD will always exist, but can be better navigated through use of a coherent framework such as PrimeD.

Keywords: *framework, in-service, integrated, professional development, STEM education, teacher education*

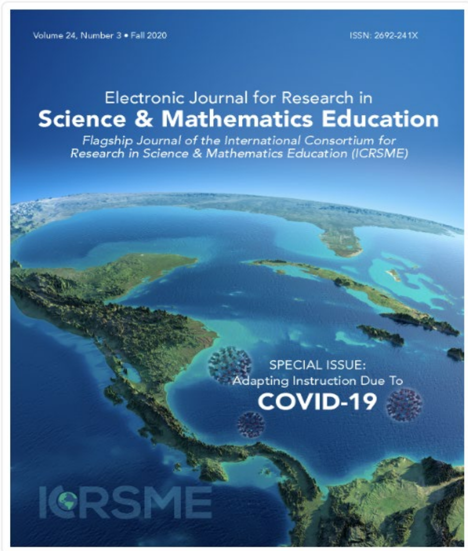
Introduction

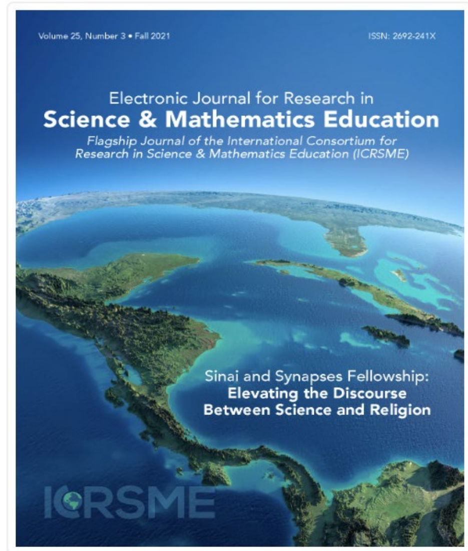
Structuring professional development (PD) experiences with a coherent conceptual framework may improve teacher experiences and increase the likelihood that the PD will change teacher professional practice (Saderholm, Ronau, Rakes, Bush, & Mohr-Schroeder, 2017). The PrimeD framework (original version published in Driskell, Bush, Ronau, Niess, Rakes, & Pugalee, 2016a) was designed to provide such a structure guiding the design and development, implementation, evaluation, and research of mathematics or science PD programs. This study examines the validity of PrimeD as a framework to guide an intervention for three integrated Science, Technology, Engineering, and Mathematics (STEM) PD programs in the United States, focused at different grade bands K-12, through a cross-case synthesis analysis (Yin, 2018). The first four authors of this paper were also each an investigator of one of the three PD programs.

We streamlined the publication timeline with four quarterly issues (Spring, Summer, Fall, and Winter) each typically containing five articles. Two categories of articles are accepted: Research/Empirical and Practice/Theoretical. The latter category opened an outlet for pieces that are not empirical yet align with the aforementioned revised scope and meet the standards of a rigorous peer-review process. We also facilitated the publication of three special issues. The first special issue stemmed from our quick response to the COVID-19 pandemic. We issued a call for shorter practitioner pieces through which educators shared how they transitioned their practice to virtual learning environments. The articles appeared across two issues of *EJRSME* in Summer and Fall of 2020 (left side of Figure 3). In Fall of 2021, Mark and guest editor, Dr. Ian Binns, published a series of articles, at the intersection of science and religion, authored by participants in the Sinai and Synapses Fellowship (right side of Figure 3). Finally, Dr. Jonathan Crocker served as guest editor for the third special issue (Spring 2023) on critical rhetorics in science and mathematics education. We invite you to consider serving as a guest editor for a special issue of *EJRSME*.

Figure 3

Covers for Two of the Special Issues





Expressing our Gratitude

As previously mentioned, the publication of each issue of *EJRSME* requires a community of colleagues who choose to dedicate their time and service to the journal. We use this last section of our final editorial to express our gratitude to these colleagues. First, we thank Dr. Molly Weinburgh and Dr. Michael Kamen, who had the foresight to see the potential of expanding the scope of the journal and merging it with ICRSME.

The process from article submission, through review, and then to publication would not function without a Managing Editor. Dr. Jonathan Crocker served as the first Managing Editor while he was completing his doctoral studies in Curriculum Studies at TCU. He learned the publication platform, designed the article template, and oversaw the logistics of bringing an issue to publication. We greatly appreciate how Jonathan paved the way for the daily operations and subsequent Managing Editors. The second Managing Editor was Dr. Morgan Jansing, who was also completing her doctoral studies in Science Education at TCU. She seamlessly transitioned to the role with Jonathan's support, learning the systems and continuing the charge of coordinating communications and article publication. We are especially grateful to Morgan for dedicating time beyond what was contracted to support the changeover to the new editorial team.

We appreciate the authors from around the world for choosing *EJRSME* as an outlet for their work, the foundation for the journal. The peer-review process of these articles is critical to maintaining the integrity of *EJRSME*. The Associate Editors oversee the review process for each article from soliciting and communicating with reviewers, synthesizing reviewer feedback, and making recommendations for publication. We recognize the three-year (or more) commitments of our mathematics education, science education, and statistics Associate Editors (Appendix A). In particular, we want to acknowledge the support of Dr. Robert Wieman, who also took on Editor responsibilities over the last year. Once an article is accepted, it is templated and copyedited. Dr. Audrey Meador has served and extended her service commitment as Copyeditor. We appreciate her dedication to *EJRSME* as well as her time and attention to detail. Of course, the peer-review process requires the time and energy of our colleagues in science and mathematics education. We thank the Editorial Review Board Members (Appendix B) and multitude of reviewers (Appendix C), who have contributed their expertise to provide thoughtful and constructive feedback on the manuscripts. Working together, all of these individuals support *EJRSME*'s contribution to the development of the fields of science, mathematics, and STEM education.

Finally, we express our gratitude to the new editorial team from the University of Oklahoma:

Dr. Kelly Feille, Science Education Editor
Dr. Jacob Pleasants, Science Education Editor
Dr. Richard Velasco, Mathematics Education Editor
Madison Morris, Managing Editor

This new team has volunteered their service to *EJRSME* for a five-year term. In fact, over the past year, they have already been working diligently in the transition. They have learned the publication system and processes, managed articles, continued to build the ERB, and taken lead on publishing the last two issues of this year's volume. We look forward to their innovation and creativity in these leadership roles as they also maintain the essence of ICRSME and *EJRSME*. Join us as we officially welcome and recognize the new editorial team.

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Appendix A
EJRSME Associate Editors Volume 24 Issue 1 to Present

Daniel Alston, *University of North Carolina at Charlotte*
Ian Binns, *University of North Carolina at Charlotte*
Lisa Ann Borgerding, *Kent State University*
Stacey Britton, *University of West Georgia*
Stephen R. Burgin, *University of Arkansas*
Sarah Bush, *University of Central Florida*
Malcolm B. Butler, *University of Central Florida*
Danxia Chen, *Dallas Baptist University*
Kelly Feille, *University of Oklahoma*
Kimberly Figaro, *Dallas Baptist University*
Heather Gallivan, *University of Northern Iowa*
Kathryn Green, *Clark County ISD*
Rita Hagevik, *The University of North Carolina at Pembroke*
Hayat Hokayem, *Texas Christian University*
Gabriela Jonas-Ahrend, *Paderborn University*
Ravinder Koul, *The Pennsylvania State University*
Stephanie Livers, *Missouri State University*
Christopher S. Long, *University of North Texas*
Erin Maher, *Georgia State University*
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Suzanne Nesmith, *Baylor University*
Samuel Otten, *University of Missouri*
Matthew Perkins Coppola, *Purdue University Fort Wayne*
Erin Peters-Burton, *George Mason University*
Sara Salloum, *University of Balamand* and *Ohio University*
Christine Schnittka, *Auburn University*
Byung-In Seo, *Chicago State University*
Julie Westerlund, *Texas State University*
Robert Wieman, *Rowan University*
Dawn Woods, *Oakland University*
Xaio Xiangquan, *Pennsylvania State University*
Ismail Zembat, *University of Glasg*

Appendix B
Editorial Review Board Members Volume 24 Issue 1 to Present

Appendix C
Reviewers Volume 24 Issue 1 to Present

Kenneth Adu-Gyamfi
Jair J. Aguilar
Franklin Allaire
Daniel Alston
Tuyin An
Christopher Anand
Cynthia O. Anhalt
Elizabeth Arnold
Kennedy Ameyaw Baah
Yejun Bae
Eleonor Regalado Basilio
Engin Baysen
Jennifer M. Bay-Williams
Cory Bennett
Robert Bennett
Daniella Biffi
Ian C. Binns
Latanya Brandon
Kristen A. Brown
Sherri L. Brown
Faye Bruun
Elissa Bryant
Lori Burch
Sarah B. Bush
R. Cavender Campbell
Amber G. Candela
Mila Rosa Librea Carden
Stacey Carpenter
Manuella Carrijo
Matthew Clay
Kimberly A. Conner
Megan Powell Cuzzolino
Rosalie DeFino
Yenealem Ayalew Degu
Jayme Kelly Del Mario
Hasan Deniz
Siddhi Desai
Andrea Drewes
Ümit Duruk
Daniel Edelen
Belinda Edwards
Mark Enfield
Barry Farris
Jenna Gist
Carlos Nicolas Gómez Marchant
Gloriana González
David Alan Goodman
Savannah Rae Graham
Stephen Gruber
Emilie Hancock
Carlie Hanlon
Michael Hast
Patrick Herak
Margret Hjalmarson
Christopher Irwin
Paul C. Jablon
Carol Renee James
Benjamin Janney
Michael Jarry-Shore
Joanna Jauchen
Tonya Jeffery
Austin R. Jenkins
Rachelle Johnson
Lee Kenneth Jones
Theresa Jorgensen
Royda Kampamba
Bona Kang
Hasan Ozgur Kapici
Dieuwertje Kast
Andrew Kercher
Candace King
Midhat Noor Kiyani
Yi-Yin Ko
Aina Jacob Kola
Ravinder Koul
Abdullah Kurudirek
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Bethany LaValley
Heather Lavender
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Rubylito Castro Luchavez
Yanping Ma
Balagopal Madhu
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Deniz Peker
Dave Pinkerton
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Debra Plowman
Maia Popova
Justin M. Pratt
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Sharon Price Schleigh
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James Ritter
Kathryn Rupe
Rachel Rupnow
Wesam Salem
Laura Schisler
Meredith Schwendemann
Ruthmae Sears
Byung-In Seo
Rafikh Shaikh
Mohammed Nader Shalaby
Joe Shane
Kristen Shelton
Minsuk K. Shim
Doras Sibanda
Michael Skoumios
Demetrice Smith-Mutegi
Alex T. St. Louis
Stasinos Stavrianeas
Samantha Strachan
Karthigeyan Subramaniam
Patrick Lane Sullivan
Gladys Sunzuma
Michael Svec
James Swart
Adem Tasdemir
M. O. Thirunarayanan
Amanda Thomas
William R. Thornburgh
Erik Tillema
Regina E. Toolin
Khanh Tran

Christelle Fayad
Markus Sebastian Feser
Lindsey Fields
Kimberly Figaro
Katherine Fogelberg
Ryan Fox
Adronisha Frazier
Jennifer Kreps Frisch
Lois George
Ihsan Ghazal
Puneet Singh Gill
Brent Gilles
Rachel Gisewhite

Eryn M. Maher
Mariam Makramalla
Robert B. Marsteller
Lloyd Mataka
Kim Megyesi-Brem
Alesia Mickle Moldavan
Alena Moon
Dana Morris
Jackson Moss
Donna Mullenax
Corey Edward Nagle
Jill Newton
Tegan Nusser

Stacy Vasquez
Richard Velasco
Stephanie Wallace
Mariah Warren
Sandy White Watson
Trena L. Wilkerson
Craig J. Willey
Dawn Woods
Gary W. Wright
Elizabeth Wrightsman
Lin Xiang
Song Xue
Christopher Yarkwah
Lili Zhou

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Effects of Using Patty Paper Practices During Geometric Constructions on Attitude, Self-Efficacy, and Achievement in Geometry

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Mugla Sitki Koçman Üniversitesi

ABSTRACT

This study aims to examine changes in students' achievement in geometry, attitude towards geometry, and their self-efficacy perception of geometric knowledge while working on paper folding activities through an experimental research methodology. The sample for this experimental study was 108 ninth-grade high school students. The study's data were gathered through attitude, self-efficacy, and achievement scales which were employed both as pretest and posttest measurements for experimental and control groups. The findings revealed a significant difference between the experimental group's pretest and posttest scores regarding the variables of achievement and self-efficacy. However, no significant difference was observed for attitude towards geometry for the experimental group. The study then addresses these results in light of the existing literature.

Keywords: geometry teaching, patty paper, paper folding, attitude, self-efficacy, geometry achievement

Introduction

Geometry plays a significant role in daily life along with mathematics. It is frequently used in architecture, art, and engineering, as well as several sub-branches of mathematics itself. Euclid's 13-volume geometry work, "The Elements," which has maintained considerable impact since 300 BCE, laid the foundation for contemporary geometry. Geometric constructions that date back to the time of Euclid are still relevant today for learning geometry, and also for mathematicians studying geometry (Pandiscio, 2002). Around 300 BCE, geometric constructions were generally created by means of a compass and a straightedge. However, the use of geometric constructions not only provides a different perspective to classic geometry teaching methods, but also reinforces the meaningful learning of geometric concepts through the promotion of mathematical thinking (Pandiscio, 2002; Serra, 2003). Geometric construction applications are considered particularly important in geometry teaching since they relate closely to the primary teaching goals of geometry, such as discovering the main axiomatic concept of geometry, proving, developing estimation capabilities, meaningful learning and problem solving, and the improvement of geometric thinking levels (Coad, 2006; Erduran & Yesildere, 2010; Leung, 2011).

The importance of geometric constructions has been emphasized in international and national standards and curricula (Australian Mathematical Sciences Institute, 2011; Common Core State Standards, 2010; Milli Eğitim Bakanlığı [Turkish Ministry of National Education], 2010a, 2010b; National Council of Teachers of Mathematics, 2000). For example, the National Council of Teachers of Mathematics Standards (2000) indicates that the use of construction tasks can help encourage students to "draw and construct representations of two- and three-dimensional geometric objects using a variety of tools" (p. 308) and "to recognize and connect mathematical ideas as a way to develop robust understandings of problems" (p. 354). Similarly, the Common Core State Standards (2010) highlighted geometric construction particularly in the Congruence section, where it advised to "make formal geometric constructions with a variety of tools and methods (e.g., compass and straightedge, string, reflective devices, paper folding, dynamic geometric software)" (p. 76). In Türkiye, the Ministry of National Education (Milli Eğitim Bakanlığı, 2010a, 2010b) drew attention to geometric construction with the "efficient use of a compass, ruler, protractor, and setsquare" (p. 18) under psychomotor skills and called for the formation of geometric constructions by promoting compass and ruler usage in model applications of mathematics curricula for several types of achievement.

Teaching environments for geometric construction should be equipped with various tools and learning strategies, with several studies in the literature having indicated that the use of different tools (e.g., dynamic geometry software, MIRA, protractor, setsquare, paper folding, compass-ruler) can help students to learn geometry more effectively (Clements & Battista, 1992). The literature includes studies on the use of paper folding in geometry teaching (Arıcı & Aslan-Tutak, 2015; Boakes, 2008; Coad, 2006; Pope, 2002), demonstrating that paper folding is a powerful yet simple teaching tool that can be used to perform geometric constructions. For example, third-degree equations can be solved through paper folding, whereas traditional tools such as the ruler and compass can only resolve equations of the second order (Geretschläger, 1995).

A study by Sanchez and Glassmeyer (2017) used patty paper to examine parabolas. The researchers utilized this material because when patty paper is folded, a white crease mark becomes visible. This makes the material useful for the examination of parabolas (Scher, 1996), ellipses, and hyperbolas (Smith, 2003) since sharp visible creases are retained after folding. Similarly, Spanik (2009) explained that a favorite lesson used patty paper to construct a unit circle and emphasized that students meticulously engaged with lessons where patty paper was used. Spanik (2009) noted that the material offered ample opportunity to clarify mathematical expressions and notations through systematic investigation to determine the exact values of sine, cosine, and tangent of 30°, 45°, and 60° angles. Draper (2007) was another mathematics teacher-researcher who stated that patty paper was a most effective tool and afforded students the opportunity to trace and fold actions in geometry and mathematics activities. King (2016) used patty paper to enhance students' understanding of piecewise functions through the use of the paper's transparency for tracing. In classes, King (2016) had students place a sheet of patty paper on the graphs of different portions of a line and a parabola within different intervals, then traced the axes onto the patty paper in order to construct piecewise functions. Additionally, Empson and Turner (2006) examined primary students' multiplicative thinking and reasoning using patty paper folding and revealed that it led to a potentially powerful development of students' thinking about fractions and multiplicative reasoning. In these studies, patty paper was notably preferred due to it being easy to fold, that the fold lines are easily distinguishable, and the paper can also be marked by students if needed. Therefore, the current study opted to utilize patty paper in place of either regular or origami paper. In recent years, the use of paper folding has been observed in geometry lessons in addition to the use of rulers, compasses, and concrete tools. Nevertheless, with patty paper often now utilized in geometric construction problems in addition to the traditional compass and straightedge method, there is a clear need to scientifically study the effectiveness of the patty paper method in both the cognitive and affective domains of geometry learning.

It is well known that the academic success of individuals is dependent upon not only on the cognitive, but also the affective dimension, with attitude and self-efficacy both key components of these dimensions. Among studies that employed various teaching methods and tools (e.g., technology, teaching through drama, concrete materials), several research studies have demonstrated that students' attitude towards geometry was more positive than where traditional teaching and learning methods were used (Duatepe, 2004; Funkhouser, 2003). In a meta-analysis study, Ma and Kishor (1997) determined that attitude and achievement were strongly related, and that students' attitude towards mathematics had negatively changed after starting school. Therefore, the examination of students' attitudes toward geometry is considered essential to understanding student performance in geometry learning.

Another affective aspect considered to influence student achievement in both mathematics (Hannula et al., 2014) and geometry (Erkek & Işıksal, 2012) relates to the concept of self-efficacy. Also referred to as self-efficacy perception or self-efficacy belief, this aspect is defined as an individual's thoughts regarding their capabilities and skill to organize their own activities (Bandura, 1986). Self-efficacy does not relate to how capable an individual is at a certain subject but is the concept of their belief in themselves. The higher an individual's belief, the more likely they are to leave failure behind them, and accordingly display ambition to attain their desired goals and achievement (Bandura, 1997). Individuals who are self-confident and feel at ease are likely to be more productive than those who are not, and in the school environment, this type of confidence may also assist learners in obtaining higher test scores. On the contrary, individuals who lack self-confidence may have low social skills and a lower chance of achievement in academic settings (Pajares, 1996). Bandura (1997) remarked on there being four basic sources of self-efficacy belief; "mastery experiences, vicarious experiences acquired through social models, verbal persuasion, and an individual's own physiological-emotional state" (p. 79). According to Bandura (1997), the most important of these four factors is "mastery experience" or life experience based on students' interpretation of their own personal performance. In research studies that addressed self-efficacy perception in relation to geometry (Karakuş, 2014; Pintrich & De Groot, 1990), it has been argued that in order to improve students' self-efficacy perception, which is generally determined as being low or average, different teaching models and tools should be employed in lessons in addition to enhanced student participation. Students' life experiences should be considered in order to support their development of self-efficacy beliefs in geometry, with appropriate environments provided in which they can encounter positive experiences. In the current study, positive student experiences were aimed to be provided through the use of patty paper folding activities in geometric construction.

Geometry is often regarded as a challenging subject that consists of many rules and thereby considered rote-based and boring by many students (Adolphus, 2011). It was also evident in studies by Mason (1998) and Mullis et al. (2012) that student achievement in geometry is lower compared to other branches of mathematics. In the current study, patty paper practices were used to teach geometric construction, and these practices were examined based on students' self-efficacy perceptions, attitudes, and achievement in geometry. Accordingly, the current study's aim was to examine the effects of patty paper practices for geometric construction on ninth-grade students' self-efficacy perceptions, attitudes, and achievement in relation to geometry. Among other methods and strategies employed for learning geometry, patty paper practices require further investigation in order to be better understood. In this respect, the following research questions form the basis of the current study:

(1) Is there a significant difference in attitudes towards geometry between ninth-grade students who participated in patty paper folding activities (over a six-week duration) for geometric construction in an "Auxiliary Elements of Triangles" unit and students who were instructed according to traditional methods?
(2) Is there a significant difference in self-efficacy perception between ninth-grade students who participated in patty paper folding activities (over a six-week duration) for geometric construction in an "Auxiliary Elements of Triangles" unit and students who were instructed according to traditional methods?

(3) Is there a significant difference in geometry achievement between ninth-grade students who participated in patty paper folding activities (over a six-week duration) for geometric construction in an "Auxiliary Elements of Triangles" unit and students who were instructed according to traditional methods?

Methodology

Research Design

Using a static group pretest, posttest design (Fraenkel & Wallen, 2006), this study compared students' pretest and posttests on measures of geometry-related attitude, self-efficacy, and achievement in order to determine whether or not a statistically significant difference was evident between the two scores. Since randomization of the students was not possible, two intact classes, which had already been formed at the beginning of the 2015-2016 school year, were used as the experimental and control groups of the study.

The design of the research is as presented in Table 1, where "O" represents the measurement tools conducted prior to and following the application. The application was divided into two, with patty paper practices conducted for the experimental group and traditional teaching for the control group.

Table 1

Pretest/posttest Design with Control Group

Group	Pretest	Application	Posttest
Experimental	O1, O2, O3	Patty paper practices	O1, O2, O3
Control	O1, O2, O3	Traditional teaching	O1, O2, O3

Note. O1: Geometry Achievement Questionnaire, O2: Attitude Towards Geometry Scale, O3: Self-Efficacy Regarding Geometry Scale.

The use of patty paper folding methods in the mathematics classroom was the treatment applied (to the experimental group) and was therefore considered as the independent variable of the study. During instruction of the "Auxiliary Elements of Triangle" unit, the experimental group performed patty paper practices, while the control group received standard traditional instruction from their teacher. The dependent variable was the students' posttest scores for the Geometry Achievement Questionnaire that had been prepared by the researcher, the Attitude Towards Geometry Scale (Bulut et al., 2002), and the Self-Efficacy Regarding Geometry Scale (Cantürk-Günhan & Başer, 2007).

Sample and Data Collection Tools

Convenience sampling was used in the selection of one high school from a medium-sized provincial center in the Aegean Region of Türkiye. One mathematics teacher from the selected high school volunteered for the study during a preliminary interview, and two of the teacher's ninth-grade classes were selected at random to be included in the study. In total, 108 students participated in the study, with 56 students forming an experimental group and 52 students as a control group, and with both groups having been taught by the same mathematics teacher.

Two existing Likert-type scales were applied in the study as well as an open-ended questionnaire developed by the researcher. The instruments used were the Attitude Towards Geometry Scale, as developed by Bulut et al. (2002), the Self-Efficacy Regarding Geometry Scale developed by Cantürk-Günhan and Başer (2007), and the researcher-developed Geometry Achievement Questionnaire. The Attitude Towards Geometry Scale consisted of 17 items and three subdimensions and was applied to both the experimental and control groups as a pretest and following the application as a posttest. The Cronbach's alpha internal consistency score of the Attitude Towards Geometry Scale was α = .92. The Self-Efficacy Regarding Geometry Scale consisted of 25 items structured under three subdimensions. In the scale's reliability test, the Cronbach's alpha coefficient was calculated as α = .87. The Geometry Achievement Questionnaire was developed by the researcher and consisted of eight geometry questions covering the "Auxiliary Elements of Triangle" topic. Each question contained either the phrase of "please prove" or "please demonstrate" (see Appendix). During its development, the questionnaire was examined by three mathematics teachers for its suitability and validity for the target class level and subject topic, and the question wording was subsequently updated in accordance with their suggested corrections.

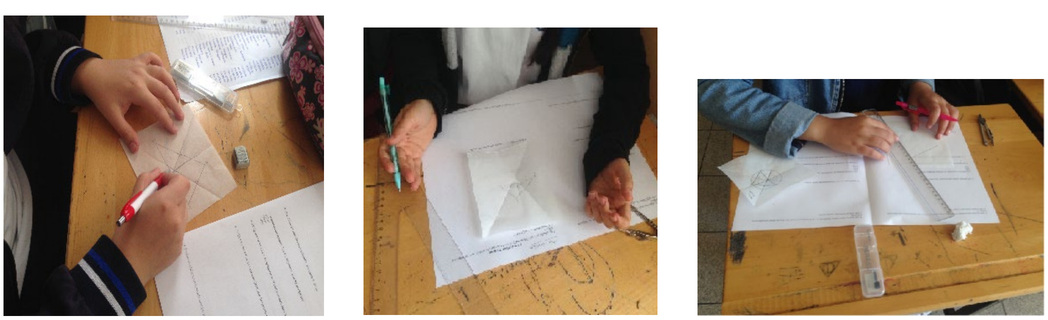
Data Collection Procedure

The research was implemented during the spring semester of the 2015-2016 academic year. The study was conducted over an eight-week period during which lessons from the "Auxiliary Elements of Triangle" sub-learning domain of the Secondary School (grades 9-11) Mathematics Curriculum for Geometry (Milli Eğitim Bakanlığı [Turkish Ministry of National Education], 2010a, b) were instructed to both the experimental and control groups of the study. For this sub-learning domain, the properties of angle bisector, altitudes, and median of a triangle were examined, and then each was discussed for each type of triangle.

In the first week of the study, preliminary application of the Geometry Achievement Questionnaire, Attitude Towards Geometry Scale, and the Self-Efficacy Regarding Geometry Scale were performed during two class hours, and these same instruments were also reapplied during the final week of the study following the application. The patty paper activities were led by the researcher for the experimental study group for a period of six weeks. During the activities certain geometry terms were emphasized, including angle bisector, interior angle bisector, exterior angle bisector, median, altitude, orthocenter, perpendicular bisector, centroid, inscribed circle, escribed circle, and circumscribed circle. These concepts were studied using a ruler, a compass, and patty paper folding activities. Views depicting the classroom practices of the experimental group are shown in Figure 1.

Figure 1

Students' Patty Paper Practices



During the patty paper activities, the instructor (researcher) distributed worksheets and afforded the students time to discuss the questions. The worksheets included questions about the related topics which the students were tasked with answering by constructing geometrical objects using patty paper. For example, in the second patty paper activity, the goal was to examine the bisector of an angle through paper folding. Instructions for folding a bisector of an angle and related questions were given in the worksheet as follows:

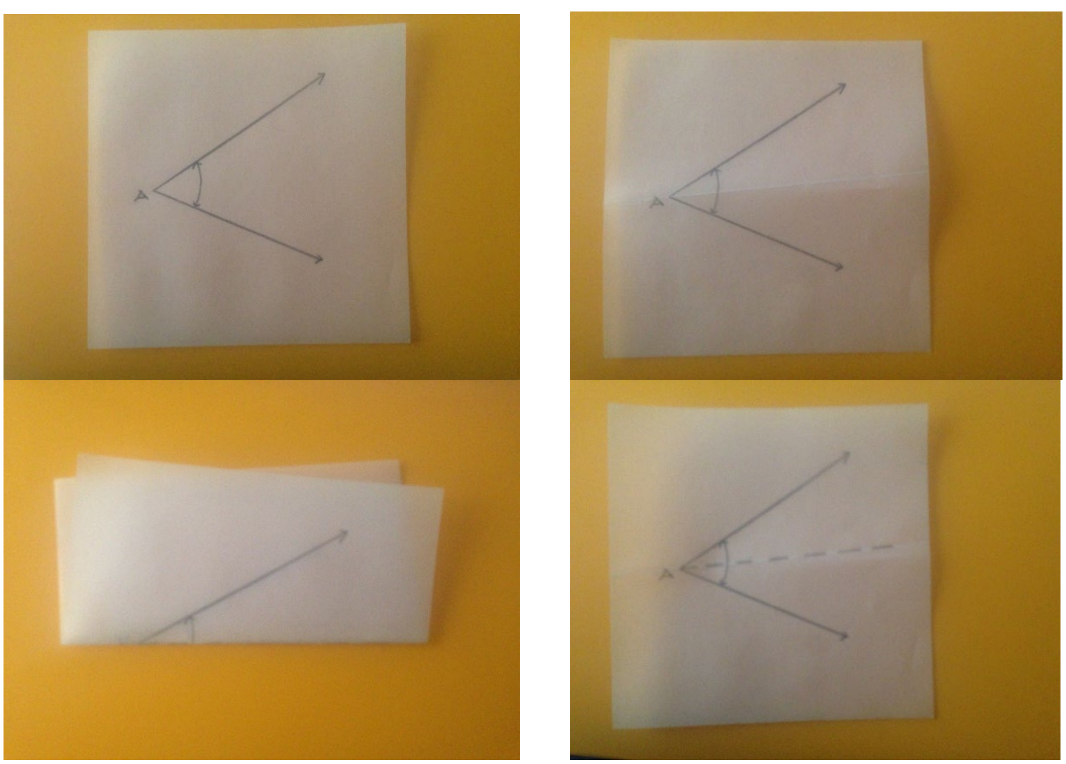
> Draw an angle on the patty paper. Fold one segment over the other ensuring that the fold passes through the vertex of the angle. Then, unfold the paper and draw along the fold line (crease). What do you think about the measurement of the angle? What changes when the angle is folded? Estimate the measurement of the two angles as they appear when the paper is unfolded.

The instructor also used patty paper during the activities. While the students were reading and folding the required geometrical concept, the instructor also folded the same geometrical concept which was then presented to the class as an example of how the task should be achieved. For students who had not understood how to construct the fold, the instructor then showed them the example and then assisted them where necessary to complete the task themselves. After the patty paper had been folded and the required concept constructed, the students answered the questions prescribed in the worksheets through peer discussion. The instructor provided assistance when the students experienced any problems reaching the correct answers or had difficulties during the patty paper task construction. The instructor helped to direct the students' discussions and led them to construct the tasks appropriately and to answer the worksheet questions.

In the following bisector construction example, the students could see the area between the two closed half lines were divided into two equivalent areas. Therefore, the closed half line represented by a dashed line in Figure 2 is referred to as an angle bisector.

Figure 2

Constructing an Angle Bisector



While the experimental group received instruction on patty paper folding with student-centered activities, the control group received traditional teacher-led instruction. In the control group, since there were no patty paper tasks, the topic of “bisector of an angle” was only shown on the whiteboard where the teacher first drew an angle and then the bisector. The teacher gave the properties of the bisector of an angle and demonstrated some bisector exercises. The control group students were knowledge receivers only and took no part in the lessons as either performers or constructors.

In addition, the researcher taught the control group origami and paper folding activities (e.g., folding crane) for one hour per week over and above their normal mathematics class time of six hours, whilst the experimental group were taught by the instructor for two hours (out of six) each week (i.e., no additional teaching hour). However, it should be noted that the one-hour weekly origami lesson offered to the control group was not associated with the content of the geometry lesson and was designed purely as an extracurricular activity. This approach was opted for in order to ensure that the researcher did not teach only one specific class and also to minimize possible effects caused by interaction between the students of either group. The two hours per week of paper folding activities conducted for the experimental group were led by the researcher (as instructor), whereas the experimental group’s remaining four hours of weekly mathematics classes were taught by their usual assigned mathematics teacher. The activities were each designed in accordance with the current mathematics curriculum in order that the class teaching schedule was not unnecessarily interrupted, meaning that the teaching schedule continued in a way that was able to encompass the activities. The practice was completed in a total of 12 hours over a period of six weeks, split equally as two hours per week. Table 2 details the content of the activities applied to the experimental group.

Table 2

Activity Content for Experimental Group

Week	Activity	Activity content
1	Introduction of folding axioms	Seven folding axioms were introduced, with each demonstrated using patty paper plus worksheet questions.
2	Drawing a bisector	Bisectors folded to a line segment from points on/outside.
3	Forming a circumscribed circle	Perpendicular bisectors found in various triangle types, circles drawn taking their intersection as center, introduced as circumscribed circle of triangles.
4	Drawing an inscribed circle	Angle bisectors found in various triangle types by folding, circles drawn taking their intersection as center, introduced as inscribed circle of triangles.
5	Forming and studying medians in triangles	Medians of sides determined in various triangle types and bisectors folded, relation between intersection of medians and median length studied.
6	Studying orthocenters in triangles	Orthocenters found in various triangle types and their intersection studied.

These two-hour sessions involved patty paper folding and examination of the folding process through worksheet questions which helped students to critique the patty paper folding process based on geometrical thinking. The paper folding and accompanying worksheet questions were aimed at helping the experimental group students to construct valid geometry knowledge.

Data analysis

Two of the three measurement tools applied in the study, the Attitude Towards Geometry Scale (Bulut et al., 2002) and the Self-Efficacy Regarding Geometry Scale (Cantürk-Günhan & Başer, 2007), are both formed as five-point, Likert-type scales, with higher scores indicating a higher level of attitude towards geometry or self-efficacy regarding geometry. In the data analysis of the scales' scores, paired sample *t*-test statistical examination was used in order to test whether or not any statistically significant differences existed between and within the pretest and posttests scores.

Findings

The findings of the study are presented in three separate foci in accordance with the study's three research questions: attitude towards geometry, self-efficacy regarding geometry, and geometry achievement.

Attitude Towards Geometry

According to the pretest test scores of the Attitudes Towards Geometry Scale, there was no statistically significant difference found between the experimental and control groups (t = -0.186; p = .822). Therefore, it can be deduced that prior to the application, the two groups of students were similar in their attitude towards geometry. However, after having conducted both a pretest and posttest of the Attitudes Towards Geometry Scale, the students in the experimental group showed no statistically significant difference in their attitude towards geometry after having received six weeks of patty paper folding instruction.

Similarly, no significant difference was found from examination of the control group's pretest and posttest scores. Although there was a decrease in the control group's mean attitude score after six weeks, this difference was not found to be statistically significant. Furthermore, upon analysis of the posttest scores of both the experimental and control groups, no significant difference was observed regarding the students' attitudes towards geometry. See Table 3 for this information.

Table 3

Experimental and Control Group t-test Results: Attitude Towards Geometry

Scale	Groups		N	$\bar{x}$	SD	df	t	p
Attitude Towards Geometry Scale	E.G.	Pretest	56	3.32	0.671	55	-1.480	.145
		Posttest	56	3.46	0.786			
	C.G.	Pretest	52	3.35	0.713	51	0.468	.642
		Posttest	52	3.32	0.773			
	E.G.	Pretest	56	3.32	0.671	106	-0.186	.822
	C.G.		52	3.35	0.713			
	E.G.	Posttest	56	3.46	0.786	106	0.955	.913
	C.G.		52	3.32	0.773			

Note. Experimental Group: E.G., Control Group: C.G., $p < .05$

From Table 3, the experimental group had increased scores ($\bar{x}_{\text{pretest}} = 3.32$, $\bar{x}_{\text{posttest}} = 3.46$) after the intervention, whereas the control group exhibited a decline ($\bar{x}_{\text{pretest}} = 3.35$, $\bar{x}_{\text{posttest}} = 3.32$). Upon comparing the two groups based on their initial attitude scores, no statistically significant difference emerged, indicating a comparable disposition towards geometry. However, whilst the mean score of the experimental group ($\bar{x}$ = 3.46) following the intervention surpassed that of the control group ($\bar{x}$ = 3.32), no statistical significance was found between them.

Self-efficacy Regarding Geometry

In order to answer the second research question of the study, the examination focused on the results from the Self-Efficacy Regarding Geometry Scale. As illustrated in Table 4, there was no statistically significant difference observed in the pretest mean scores between the experimental ($\bar{x}$ = 3.01) and control groups ($\bar{x}$ = 3.06), suggesting that students in both groups exhibited similar levels of self-efficacy at the onset of the study. However, following the six-week treatment period, notable differentiation emerged between the pretest and posttest mean scores of the experimental group, where the paper folding approach of instruction had been employed (see Table 4, $\bar{x}$ = 3.41, *SD* = 0.587, $t(106) = 2.238$, $p < .005$).

Table 4

Experimental and Control Group t-test Results: Self-Efficacy Regarding Geometry Scale

Scale	Groups		*N*	$\bar{x}$	*SD*	*df*	*t*	*p*
Self-Efficacy Regarding Geometry Scale	E.G.	Pretest	56	3.01	0.518	55	-5.405	.000*
		Posttest	56	3.41	0.587			
	C.G.	Pretest	52	3.06	0.577	51	-1.140	.259
		Posttest	52	3.14	0.662			
	E.G.	Pretest	56	3.01	0.518	106	-0.462	.343
	C.G.		52	3.06	0.577			
	E.G.	Posttest	56	3.41	0.587	106	2.238	.027*
	C.G.		52	3.14	0.662			

Note. Experimental Group: E.G., Control Group: C.G., * $p < .05$

In contrast, there was no significant difference detected between the pretest ($\bar{x}$ = 3.06) and posttest mean scores ($\bar{x}$ = 3.14) of the control group's students. This indicates that the self-efficacy scores of the control group remained largely unchanged after having received traditional geometry instruction in their lessons. Conversely, comparison of the posttest mean scores ($\bar{x}_{E.G.}$ = 3.41, $\bar{x}_{C.G.}$ = 3.14) indicated that there is a significant effect of the patty paper folding approach on the ninth grade students' self-efficacy in geometry (see Table 4, $\bar{x}$ = 3.41, *SD* = 0.587, $t(106) = 2.238$, $p < .005$).

Geometry Achievement

Scores taken from the Geometry Achievement Questionnaire were used to test the third research question and the third quantitative assessment of student performance applied in the study. Initially, there was a noticeable difference in performance on the Geometry Achievement Questionnaire pretest. The control group statistically performed better than the experimental group ($\bar{x}$ = 9.48, SD = 7.41, $t(106) = -3.44$, $p < .005$). This finding suggests that the control group was comprised of students with a higher level of geometry knowledge when compared to the experimental group.

However, as shown in Table 5, a significant difference was observed between the pretest and posttest mean scores of the Geometry Achievement Questionnaire for the experimental group, after having been engaged in patty paper folding practices ($\bar{x}$ = 8.41, *SD* = 6.60, *t*(55) = -5.062, *p* < .005). The difference in scores between the pretest and posttest indicated that the use of paper folding practices had a positive effect on the experimental group's geometry achievement level.

Table 5

Experimental and control group t-test results: Geometry Achievement Questionnaire

Scale	Groups		*N*	$\bar{x}$	*SD*	*df*	*t*	*p*
Geometry Achievement Questionnaire	E.G.	Pretest	56	5.34	4.95	55	-5.062	.00*
		Posttest	56	8.41	6.60			
	C.G.	Pretest	52	9.48	7.41	51	-1.235	.223
		Posttest	52	10.04	7.56			
	E.G.	Pretest	56	5.34	4.95	106	-3.44	.00*
	C.G.		52	9.48	7.41			
	E.G.	Posttest	56	8.41	6.60	106	-1.195	.235
	C.G.		52	10.04	7.56			

Note. Experimental Group: E.G., Control Group: C.G.,*$p < .05$

No significant contrast was observed between the mean pretest and posttest scores of the Geometry Achievement Questionnaire among students in the control group. However, despite the lack of statistical significance, it is notable that there was an overall improvement in their achievement scores. Similarly, when looking at the posttest scores for geometry achievement between the experimental and control groups, no substantial difference was found. This could be explained by the control group having had higher achievement mean scores even before the treatment began when compared to the experimental group, indicating that the control group consisted of students who were generally more academically successful. However, upon closer examination of the mean pretest and posttest scores for the experimental group, there was a noticeable increase in the students' geometry achievement levels (see Table 5).

Based on the data provided in Table 5, it is evident that the utilization of the patty paper folding approach had a discernible impact on the geometry achievement of the experimental group's students. Conversely, the control group's students did not exhibit any significant variance in their geometry achievement scores. When comparing the pretest results in geometric achievement between the two groups, a notable finding emerges. A significant disparity in the average scores was shown, with the control group outperforming the experimental group. This difference can be explained by the fact that the students in the control group initially performed at higher levels. However, what is particularly noteworthy is the lack of any significant mean difference between the posttest scores of the experimental and control groups. This finding indicates that the introduction of paper folding activities enabled the experimental group to bridge the gap in achievement, bringing their scores closer to those of the higher-performing control group.

Discussion

The aim of this study was to evaluate the influence of paper folding activities on the geometry achievement, attitudes, and self-efficacy perceptions of ninth-grade students. A six-week treatment period was implemented, and inferential statistics were utilized in the analysis of the obtained data. This section presents the results of the study in accordance with the findings.

The results suggested that the experimental group who participated in paper folding activities experienced considerable gains in their geometry achievement. This result was similar to that revealed in several prior studies in the literature that established achievement as having increased through the application of different teaching methods (e.g., technology, compass-ruler use, origami) in geometry lessons (Arıcı & Aslan-Tutak, 2015; Güven, 2006; Napitupulu, 2001). The cause behind such increases may be interpreted such that these alternative practices help enable learners to actively form geometric constructions and to reach conceptual understanding and explanations more easily, unlike traditional methods. For instance, Güven (2006) found that geometric drawing instructed by means of paper folding and compass-ruler use for seventh and eighth grade students for a period of six weeks helped geometry success levels and saw a positive attitude change towards geometry. Similarly, Arıcı and Aslan-Tutak (2015) found that students who were taught geometry using origami for four weeks had significantly higher achievement compared to the control group. Unlike the findings of Güven (2006) and Arıcı and Aslan-Tutak (2015), the current study observed that the use of patty paper folding did not significantly affect the experimental group's attitude towards geometry. Similarly, Hull and Brovey (2004) determined that their experimental group was more successful with regards to geometry achievement, but that no significant difference was identified with regards to the students' attitudes. The main reason behind this finding may be that the time required to observe such a change is longer and that longer-term practices are required. For example, Hull and Brovey (2004) applied an implementation over a period of three weeks, whereas the current study was based on a treatment period that spanned six weeks. Thus, it would be beneficial for the process to be repeated in a longer-term study and the results subsequently comparatively analyzed. The questions used in the current study's Geometry Achievement Questionnaire were open-ended and required the students to provide explanation, which is another potential justification for the absence of any difference in the experimental group's geometry achievement. The participants of both the current study's control and experimental groups were unfamiliar with these kinds of open-ended questions, being more accustomed to answering multiple-choice questions requiring no additional explanation. Therefore, the participant students may have experienced difficulties in answering the open-ended questions they faced in the Geometry Achievement Questionnaire.

The results regarding another variable of the current study, self-efficacy perception, are considered to be of particular importance. Although no change in attitude was observed, the experimental group's self-efficacy perception exhibited a significant positive difference. The cause of this improvement may be explained by means of elements reported by Bandura (1997) as the sources for the development of self-efficacy, or the lack thereof. In the current study, the researcher continuously provided verbal confirmation and cues to the students, underlining that geometry may be an easier subject than they thought (verbal persuasion), which was reinforced by their having witnessed the achievements of their peers (indirect experience) and may be proposed as the cause for the observed change in self-efficacy. Furthermore, patty paper practices, which may be regarded as direct experience for the students, may also be considered a factor for positive change in self-efficacy as they largely formed abstract concepts by themselves and experienced geometry subjects as a phenomena that may be studied concretely. Similarly, Usher and Pajares (2008) remarked that the successful experiences of individuals in their lives could enhance self-efficacy beliefs.

Consistent with prior research by Lam and Pope (2016), one of the most significant results of the current study was that introducing paper folding into geometry lessons helped to enhance the students' motivation and self-confidence. For this reason, the use of paper folding activities is recommended to help improve class/activity involvement of students who generally experience anxiety or lack of self-confidence, particularly in relation to geometry lessons, to increase their motivation and thereby enhance their self-confidence, as well as their attention and interest during classes.

Based on an additional observation about psychomotor skills, the students notably experienced difficulties in the use of a compass, which may relate to there being no integrated compass application during classes as the reason behind this observation. It was noted that the mathematics teachers had not used any geometrical tools during the lessons, focusing instead on the solving of theoretical geometry questions, despite the mathematics curriculum clearly indicating that the "compass-ruler or their counterpart in dynamic geometry software should be used." The reasons underlying teachers' unwillingness to use such tools could be that "they were unable to perform geometric drawings" and that "they do not place the required importance on geometric drawings," as emphasized in the findings of Erduran and Yesildere (2010), leading to the students' lack of knowledge and skills required for the formation of geometric constructions. The result of a study by Napitupulu (2001) also produced findings whereby secondary education geometry students could not acquire the required skills for geometric constructions.

It may be argued that the difficulties experienced by the current study's students in folding patty paper was that they had not previously performed any paper folding activities. In earlier research, the researcher pointed out that paper folding should be performed a number of times in order to familiarize students with the general process of paper folding and to then study these processes with regards to mathematics (Boz, 2015). This approach would help students to develop the required fine motor skills and the ability to use multiple organs (e.g., eye, hand) simultaneously during paper folding activities. Having gained experience at paper folding, students would be likely to perform better in geometry-based paper folding activities.

Suggestions

The formation of geometric constructions has been integral to both mathematics and mathematics teaching for centuries. However, these practices should be studied more with respect to geometry teaching and are deserving of greater attention in the teaching and learning of geometric concepts. It is contemplated that, based on the findings of the current study, the literature would benefit considerably if comparisons were made between classes where patty paper practices were performed and where other tools were used and to provide experimental findings. In addition, comparisons could be made between classes where dynamic geometry software and a compass-ruler were employed, and where paper folding activities were undertaken. Moreover, the current study also proposes that the literature would benefit from lesson planning that incorporates all of these processes; that is, paper folding activities followed by compass and ruler application, then supported by the use of dynamic geometry software, and finally testing the effectiveness of these approaches. The results of the current study suggest that geometry teachers could consider using paper folding activities in their lessons to develop students' geometry knowledge and geometrical thinking. Patty paper activities have the potential to improve students' achievement, positive attitude towards geometry, and self-efficacy perception with regards to geometry. However, it should be noted that students may need additional support during patty paper activities, hence teachers should develop appropriate strategies and pedagogical tools to scaffold students' geometry learning during such activities. These scaffolding types could also be examined in future studies.

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Appendix: Geometry Achievement Exam

(1) “Points that are at equal distance to two points, are a line that is perpendicular to the line segment that connects these two points.” Please demonstrate the expression by drawing and explaining why it is perpendicular.

(2) “In a triangle, interior angle bisectors intersect at a point.” Please demonstrate the expression by drawing and explaining why they intersect.

(3) “In a triangle, altitudes intersect at a point.” Please demonstrate the expression by drawing and explaining why they intersect.

(4) “In a triangle, bisectors intersect at a point.” Please demonstrate the expression by drawing and explaining why they intersect.

(5) “In an isosceles triangle, auxiliary elements of the equal sides are equal between themselves.” Please demonstrate the expression by drawing and explaining why they are equal.

(6) “In an equilateral triangle, all auxiliary elements are equal.” Please demonstrate the expression by drawing and explaining why they are equal.

(7) “If all corresponding sides of two triangles are equal, then the triangles are equal and the measurements of angles facing the equal sides are also equal.” Please demonstrate the expression by drawing and explaining why they are equal.

(8) “In a triangle, two external angle bisectors and a third internal angle bisector intersect at a point.” Please demonstrate the expression by drawing and explaining why they intersect.

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A Retrospective Examination of STEM Teachers' Use of Project-based Learning Once Employed

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ABSTRACT

This study explored science and mathematics teachers' knowledge and beliefs about project-based instruction (PBL). Data included two focus groups, and a 12-item questionnaire administered to 138 teachers. The response rate was 70% (n=96). Results show strong teacher knowledge of PBL Gold Standard Design Elements/Teaching Practices, but low usage by teachers (68%) as less than 26% of instructional time was used to implement PBL. Of the respondents, 33 indicated they used PBL as a teaching strategy. Teachers felt prepared to use PBL, suggested it made learning fun, and helped students acquire academic content and 21st century skills. Challenges included: funding support, accountability requirements, time constraints, and lack of professional development support.

Keywords: project-based learning, PBL, secondary science education, secondary mathematics education

Introduction

Educator preparation programs should advance and strengthen the teacher pipeline in ways that support PK-12 learning. As part of this effort, programs rely on evidence to evaluate and continuously seek to improve. Although Texas produces the largest number of mathematics and science teachers in the United States (Marder, 2020), teacher shortages in this area persist with almost four out of 10 teachers having not more than five years of experience (Landa, 2024). For this reason, this program focused on the preparation of mathematics and science teachers in an effort to develop quality teachers who will remain in the classroom. This program began as part of a national effort spearheaded by the UTeach Program to replicate a proven approach to prepare STEM teachers. One part of the teacher preparation curriculum includes problem-based learning (PBL) to help students acquire knowledge and skills that are useful in life by investigating relevant, real-world problems. As faculty are concerned with continuous program improvement and providing teachers with a research-based teaching practices, we wanted to know to what extent teachers used PBL once they became a classroom teacher. Specifically, this study investigated the knowledge and beliefs of newly certified science and mathematics classroom teachers who received teacher training and early field experiences in PBL as part of their pre-service training. This study addresses a gap in the literature as it seeks to examine if mathematics and science teachers actually implement the teaching model of PBL once they become a classroom teacher.

This study used the Buck Institute for Education (n.d.) formal definition for PBL, *a teaching method in which students gain knowledge and skills by working for an extended period of time to investigate and respond to an authentic, engaging, and complex question, problem, or challenge.* As such, PBL is a method that takes advantage of students' inherent drive to learn as they engage in a deep exploration that is designed to construct essential knowledge. The students' investigation uses both tools and skills to generate products that result from sustained inquiry, accompanied by recursive feedback and performance-based assessment. It should not be overlooked that design criteria for PBL must include the development of *new* skills and the construction of *new* knowledge, and it is the project requirement infrastructure that supports and structures the development of these new skills and knowledge.

The following research question was used to examine how teachers use PBL design and practices once they become certified teachers and are employed as a teacher of record:

> After participation in 70 hours of PBL instruction as a pre-service teacher, which of the Gold Standard PBL project design elements and PBL practices do in-service teachers report using as part of PBL design and implementation?

Framework for the Study

The Gold Standard PBL Model is the framework used for this study. The framework includes both essential design elements for developing high-quality projects together with teaching practices to help teachers and others to assess and continuously improve their practices. All design elements *and* project-based teaching practices focus on the development of key knowledge commonly associated with discipline standards, understanding, and success skills (i.e., critical thinking, collaboration, communication, and creativity). These elements set the stage for learning and should be emphasized throughout the project. The seven essential project-design elements (Buck Institute for Education, n.d.; PBL Works, 2022) include: (1) a challenging problem or question; (2) sustained inquiry; (3) authenticity; (4) student voice and choice; (5) reflection; (6) critique and revision; and (7) public product. In addition to the PBL design elements, this study examined project-based teaching practices for Gold Standard PBL (Boss & Larmer, 2018; PBL Works, 2022). These practices include: (1) Building the Culture; (2) Designing and Planning; (3) Aligning to Standards; (4) Managing Activities; (5) Assessing Student Learning; (6) Scaffolding Student Learning; and (7) Engaging and Coaching.

Literature Review

Origins of PBL

The project method can be traced back to 1577 to master builders in Rome who sought to advance their standing through the development of a profession through science and education. More than 150 years later, design problems (projects) were given to advanced students of the Academie Royale D'Architecture in Paris to demonstrate that they could apply what they had learned into practice in the design of structures such as bridges, fountains, and churches (Phillips, 2014). From these early projects, three models developed. The linear model first taught skills then applied them to projects (Woodward, 1887). The holistic model moved the project from the end of the unit by placing students together to plan, learn skills, and ultimately construct a project. Instruction in the holistic model was an integral part of project construction that accompanied, but did not precede, the project (Richards, 1906). Finally, the universal model put forth by William Kilpatrick (1918) was strongly child-centered and generic in nature. There was no prescribed curriculum, and ideally the project was proposed and carried out by the students themselves. Kilpatrick (1918) included student motivation as an essential component of the project method, and created a typology of projects that did not link to specific subjects, nor did it require any active doing in terms of physical activity. It is interesting to note that Kilpatrick's (1918) concept was never successfully implemented, although his article, *The Project Method,* remains a classic text.

Even though Kilpatrick is often called the Father of the Project Method, he was fiercely criticized by prominent educators, philosophers, and social reformers of his time including Dewey, Thorndike, Horn, Charters, and Bode who outlined serious weaknesses in the Project Method (Phillips, 2014). Those weaknesses included: the claim that only the interests of the child would lead to the best results in learning; a lack of teacher guidance for issues related to subject matter, classroom management and student performance; promulgation of freedom that gave rise to selfish and individualistic attitudes in place of democratic and social virtues; and masquerading as a method of teaching instead of a philosophy of education (Phillips, 2014).

PBL and Dewey

It is the work of Dewey at the Laboratory School at the University of Chicago that clearly positioned the teacher as the guide for learning and not the student themselves. Dewey (1934) stated,

> It is the business of the educator to study the tendencies of the young so as to be more consciously aware than are the children themselves what the latter need and want. Any other course transfers the responsibility of the teacher to those taught. (p. 85)

Dewey's philosophy included three components of Herbartian thought; the psychological, the sociological and the logical.

First, the natural impulses and interests of children was to be used by the teacher to draw them to the learning topic. Dewey identified four interests possessed by all children: communication, making and building, exploring and investigating, and artistic expression and self-realization. Thus, the main function of the teacher was to take the curriculum and transform it into problems that students could investigate in authentic ways, and on their own, with little direction from the teacher (Knoll, 2014). In Dewey's view, the student was not capable of planning projects and activities, so they needed a teacher to provide guidance and direction to ensure that learning would occur (Rohr & Lenhart, 1995). All teaching methods were rooted in scientific thinking and the method of the educative experience. The second component of Herbartian thought utilized by Dewey held that children were to gain sociological components that would enable them to take part in democracy. The factors of socialization, namely, common aims where interchange of thought is prevalent, a spirit of cooperation, and division of labor that binds students together were resulting sociological components. Lastly, as a result of the learning experience, the students would learn content and methods that would contribute to a progressive society. In addition to Dewey's philosophy, project-based instruction is also situated in constructivism, an activity-based learning where children explore and engage in learning as a process used to create meaning (Greeno, 2006; Oguz-Unver & Arabacioglu, 2014).

PBL Impact on Students

Currently, PBL has grown in popularity as an alternative to direct instruction (Ogus-Unver & Arabacioglu, 2014) with its focus on a student-centered setting (Kokotsaki et al., 2016) and with projects functioning as the core of the curriculum (Krajcik & Shin, 2014). It should be noted that PBL has often been used in the sciences (Krajcik & Shin, 2014; PBL Works, 2022; Rogers et al, 2011) and in mathematics (Chen & Yang 2019; Han et al., 2015; Holmes & Hwang 2016). Importantly, PBL has been shown to increase student motivation (Krajcik & Czerniak, 2018), as well as well as student interest in content (Barak & Asad, 2012; Bell, 2010; Holmes, 2011), engagement in learning (Almulla, 2020; Bender 2012; Tseng et al., 2013), increasing academic achievement (Chen & Yang, 2019) and metacognition (English & Kitsantas 2013; Thomas, 2008).

A meta-analysis by Chen and Yang (2019) explored academic achievement associated with PBL and found a large positive effect on academic achievement when compared to direct instruction. These authors also found the mean effect size was influenced by subject (social sciences was best), hours of instruction (at least two hours), and technology support (particularly with teacher knowledge of how to use technology to support learning (Eskrootchi & Oskrochi, 2010). The comparison of PBL to direct instruction also showed that group size did not affect achievement, nor did educational stage (i.e., primary, secondary, college).

Teaching and PBL

There are a few studies about the use of the PBL model experienced by secondary mathematics and science pre-service teachers once they become teachers of record (Burlbaw et al., 2013; Chen & Yang, 2019; Gijebels et al., 2005; Han et al., 2015; Hasni et al., 2016; Kanter, 2009; Krajcik & Shin, 2014; Walker et al., 2011). That is, studies that focus on whether preservice teachers enact in the classroom what they studied as a pre-service teacher while in the university or via significant professional development. As instruction for PBL is negotiated collaboratively between the teacher and the student(s), conceptualization of PBL by the teacher is critical for implementation (Fallik et al., 2008; Tsybulsky & Muchnik-Rozanov, 2019). Specifically, there is more to it than understanding the surface features associated with PBL (i.e., product, collaboration, autonomy). Rather, it is the core features (i.e., contextualized problem or question, product with a purpose, application of conceptual knowledge, inquiry) for which the teacher must show adequate knowledge and experience about in order to successfully negotiate learning and enable students to develop their own ideas and grow their own knowledge and skills (Grossman et al., 2018; Harrell et al., 2022; Kavanaugh & Rainey, 2017; Kavanagh et al., 2020; Kloser et al., 2019; Subramaniam et al., 2020).

Hasni and colleagues (2016) conducted a meta-analysis that included how teachers express the concepts and features of PBL. In that study, the main features used to define PBL included an authentic question or problems, engagements in design activities or investigations, collaboration, use of technology, and a final product (Krajcik & Shin, 2014; Parker et al., 2013). The teachers' justification for use of PBL included the learning of specific knowledge and skills that were situated in real world settings or practices; increases in student motivation; and the benefits of constructivist practices to enhance learning.

With these advantages in mind, it should not go unsaid that PBL can be a difficult practice to master. Challenges described by the teachers included managing the features of the model, such as formulating a problem or question (Krajcik & Shin, 2014), using inquiry (Veletsianos et al., 2016), access to resources, supporting claims (PBL Works, 2022), time constraints (Dole et al., 2016), and balancing monologic interactions with student discussions (Fallik et al., 2008; Larmer et al., 2015).

There are also a limited number of studies that show gains in teacher knowledge and confidence after engaging in professional development around PBL. For example, Gijebels and colleagues (2005) studied the impact of a PBL professional development on calorimetry and body systems in biology and showed higher levels of both content knowledge and pedagogical content knowledge for teachers' intervention (Gijbels et al., 2005). Walker and colleagues (2011) also found PBL was associated with large increases in teacher content knowledge and confidence along with technology integration.

Using an experimental design, Hixson and colleagues at the West Virginia Department of Education (2012) conducted a large study that compared the performance of teachers trained by the Buck Institute for Education in PBL to those who did not receive training. These authors found that trained teachers implemented 21st century skills more frequently and more extensively, regardless of content area, students served, or the presence of block scheduling. Similarly, Häkkinen and his associates (2017) demonstrated that PBL developed 21st century skills by promoting critical thinking, problem-solving, communication, teamwork, and creativity.

With regard to instruction, balance of direct instruction with inquiry allows students the opportunity to gain deeper understanding of content and processes (Arantes do Amaral et al., 2015; Grant, 2011; Grant & Branch, 2005; Markham, 2012; Özel, 2013; Veletsianos et al., 2016) while assessment practices trace and document mastery of knowledge and practices (Grant & Branch, 2005). Scaffolding, another important aspect of instruction, drives and supports student learning, allowing for opportunities to understand and take advantage of learning in ways that identify and bridge prior knowledge while addressing learning gaps (Arantes do Amaral et al., 2015; Gresalfi et al., 2012; Hmelo-Silver et al., 2007). Finally, it has been shown that the PBL approach provides the opportunity for inexperienced teachers to engage in transformative learning experiences, while supporting both professional and personal development (Tsybulsky & Muchnik-Rozanov, 2019).

Methodology

The purpose of the study was to examine teachers' use of PBL design and practices once employed as a certified teacher (i.e., teacher of record). Given this statement of purpose, the study used focus groups and data from a questionnaire to explore how employed teachers who graduated from a science and mathematics teacher program used, or did not use the PBL teaching method. For those who were using it, this study explored the teachers' use of project design elements and project-based teaching practices. Institutional Review Board approval was granted for this study (No. 17-322) and SPSS Version 25.0 was used to analyze the data. The following research question was used to guide the study.

> After participation in 70 hours of PBL Instruction as a pre-service teacher, which of the Gold Standard PBL project design elements and project-based teaching practices do in-service teachers report using as part of PBL design and implementation?

In an effort to obtain rich data from a select constituency, a traditional purposive sampling technique was used in this study. According to Teddlie and Tashakkori (2009), "purposive sampling techniques involve selecting certain units or cases based on a specific purpose rather than randomly selecting" (p.173). Data collected and reported in this this study also follows the American Psychological Association's (2019) publication *Race and Ethnicity Guidelines in Psychology: Promoting Responsiveness and Equity.*

Participants

Participants in this study attended an R1 University that was Council for the Accreditation of Educator Programs (CAEP) accredited. Both science and mathematics programs were nationally recognized by CAEP, meaning students were provided a program of quality experiences that had undergone a rigorous external peer-review process by the academic community and other stakeholders. This program is one of 11 original UTeach replication projects that received five years of financial support and extensive feedback from UTeach. The purpose of UTeach is to establish innovative secondary math and science teacher preparation programs that successfully recruit, train, and retain excellent teachers to work in diverse high-need school settings (UTeach, 2024). The PBL course is part of this replication.

The ethnicity of the participants was determined using university records where ethnicity is self-reported: 10% Asian, 9% Black, 21% Hispanic, 52% White, and 9% did not report their ethnicity. Science and Mathematics teachers were almost equally represented as 45 (49.45%) were Mathematics teachers and 41 (45.05%) were Science teachers. The five remaining teachers (5.49%) were multidisciplinary teachers. Percentages do not equal 100% due to rounding.

All participants received a degree in their content area, such as a BA in Mathematics, BA in Biology, or BA in Chemistry, along with a minor in education that included teacher certification. Participant grade point averages were a minimum of 2.8 on a 4-point scale, a condition of CAEP accreditation. As part of the education coursework, students completed a 45-hour course in PBL, *Project-based Instruction in Math, Science and Computer Science* that included significant field experiences in a PBL school. It is this undergraduate pre-service teacher experience and whether or not it was enacted in the classroom as an in-service teacher (teacher of record) that is the focus of this investigation.

Data Sources and Instrumentation

Focus Groups

Data produced from focus groups is generally rich data in that it provides the opportunity to uncover complexities through rich descriptions (Hesse-Biber & Leavy, 2011). According to Hesse-Biber and Leavy (2011), "focus groups have a distinct advantage over other available research methods when the researcher doesn't know all of the issues surrounding a topic" (p.163). A focus group for science teachers and a separate focus group for mathematics teachers was used to identify themes about knowledge and implementation of PBL. The Science focus group included six female, first-year teachers, and the Math focus group included five first-year teachers (one male and four female). All were program graduates and reported implementing a PBL unit in their classroom.

For each of the two focus groups, structured interviews were used by the authors who adhered to the transcription process as described by Mergenthaler and Stinson (1992). Participants were selected because of their rigorous preparation as an undergraduate, and their content expertise in science or mathematics. The data were transcribed using a transcription service approved by the university review board.

Three of the five authors initially reviewed and manually coded the transcripts thematically. Differences in coding were resolved through a process of consensus (Braun & Clarke, 2006), that is the three authors consulted each other about how they applied codes to the focus group transcripts and sought to correspond themes to participants' constructions of implementing PBL in their classrooms as expressed in their focus group interview transcripts. Intercoder agreement (Kurasaki, 2000) was used as a trustworthiness technique in this study. In seeking agreement on a consensus on preliminary themes, an 80% coherence was sought between each author's applied codes and preliminary themes.

Questionnaire

Based on these identified themes from the focus groups, together with selected questions from the National Survey of PBL and High School Reform (Ravitz, 2008), a questionnaire was developed. The questionnaire used duplicate questions from the National Survey of PBL and High School Reform

(Ravitz, 2008), combined with questions utilizing the focus group themes. Twelve questions with varied Likert scale ratings tailored to the question were created to describe teacher knowledge of PBL design and teaching practices The face validity was established via three experts who evaluated the questions' effectiveness regarding capturing the topic under investigation. As a result, the questions were refined, and the response scale was changed to include verbal labels. This was done in an effort to reduce ambiguity in the translation of subjective responses and to clarify the meanings of the scale points. Next, the questionnaire was piloted with mathematics and science teachers and their feedback was used to further improve the context and clarity of the questions. Due to the nature of the purposive sampling, which was predetermined and included only math or science teachers, the sample population was small and did not allow for further examination of the underlying components. The data collected from the questionnaire was used to provide a generalizable view of teachers' beliefs regarding PBL and utilization of PBL practices in their classroom while the teacher of record.

Reliability analysis was not conducted for this study due to the small sample size. Kline (1986) cautions against performing analysis for samples fewer than 300. Although there is some support for reliability analysis for smaller sample sizes (Nunnally, 1994; Yurdugul, 2008), Samuels (2017) cautions that attempting analyses on samples fewer than 30 is not feasible. The questionnaire was electronically mailed to 138 science and mathematics teachers who were graduates from a teacher education program for mathematics and science at a large university in North Texas. Follow up reminders were provided twice in an effort to improve the response rate of the questionnaire.

Results

Of the 138 teachers in the sample, 96 responded to the questionnaire and 91 participants completed the questionnaire. According to Nulty (2008) and Van Horn (2009) this is respectable response rate. Of the 96 teachers who responded to the questionnaire, 33 (34.38%) indicated that they used PBL as an approach to instruction based on the following criteria: engaged students in an extended investigation; required in depth inquiry into a topic; included student self-direction (voice and choice); and presented findings, results, or conclusions. Of the 33 respondents, 25 finished all questionnaire items. The 25 teachers who completed the questionnaire are the focus of this study.

Context

Of the 25 teachers who used PBL and completed the questionnaire, fourteen were mathematics teachers, ten taught science, and one taught in an interdisciplinary setting. All but one teacher taught in a secondary school setting and teachers were assigned to preparations that spanned different grade levels (grades 9 – 12). Almost all teachers taught in block or flexible school settings (87%) with a school-wide emphasis on problem-based, project-based, or inquiry learning (76%) and a school-wide emphasis on acquisition of 21st century skills (100%). Seventeen teachers (68%) indicated they spent 25% or less instruction time using PBL. Three teachers (12%) indicated they spent approximately 50% of instructional time facilitating PBL, with an equal number spending 75% of their time, and two teachers (8%) used PBL exclusively for instruction. Outside of the 70 hours of training the teachers received as an undergraduate, little professional development was provided as a teacher in the classroom that would support the use of PBL. Eleven teachers (44%) received no professional development training, ten teachers received a half or one day of training (40%), and four teachers (16%) received 4 or more days of training that supported the use of PBL.

Beliefs about Students and Use of PBL

As shown in Table 1, all teachers expressed the belief that PBL is an effective teaching strategy for high-achieving and average-achieving students (Barak & Asad, 2012; Bell, 2010; Chen & Yang, 2019; Holmes, 2011).

Table 1

Teacher Beliefs about the Use of PBL for Various Student Populations

	Strongly Disagree	Tend to Disagree	Not Sure	Tend to Agree	Strongly Agree
High Achieving Students	0 (0%)	0 (0%)	0 (0%)	3 (12%)	22 (88%)
Average Achieving Students	0 (0%)	0 (0%)	0 (0%)	9 (36%)	16 (64%)
Low Achieving Students	3 (18%)	4 (25%)	1 (06%)	8 (50%)	0 (0%)
Students Who Lack Motivation	2 (8%)	2 (8%)	4 (16%)	10 (40%)	7 (28%)
Student with Limited English Skills	1 (4%)	2 (8%)	4 (16%)	9 (36%)	9 (36%)

Note. Not all teachers responded to this item.

Sixteen of twenty-five teachers responded to the question regarding low-achieving students and eight out of 16 teachers (50%) indicated its use with low-achieving students. Seventeen of twenty-five teachers (68%) indicated PBL was appropriate for students who lack motivation, with four teachers (16%) "not sure" and four teachers (16%) who disagreed to some extent about its usefulness with students who lack motivation. Similarly, 18 teachers (72%) agreed to some extent that PBL could be used with students who have limited English skills, while four teachers (16%) were "not sure" and three teachers disagreed to some extent.

Beliefs About Challenges that Limit the Use of PBL

Similar to other studies, 40% of teachers considered student proficiency/familiarity with PBL and the time needed to carry out a project as major challenges that limited the use of PBL (Dole et al., 2016; Fallik et al., 2008). As shown in Table 2, moderate challenges included too many students (44%), a lack of funding or resources (32%) finding time to create or plan projects (28%), lack of PBL examples in the subject area (24%), and testing and accountability requirements (24%).

Table 2

Teacher Challenges that Limit Use of PBL (n = 25)

	Not a Challenge	A minor Challenge	A moderate Challenge	A Major Challenge
Too many students	1 (4%)	10 (40%)	11 (44%)	3 (12)
Short class periods	10 (40%)	7 (28%)	4 (16%)	4 (16%)
Classroom space	8 (32%)	8 (32%)	5 (20%)	4 (16%)
Student proficiency with PBL	3 (12%)	7 (28%)	5 (20%)	10 (40%)
Attendance and/or student behavior	8 (32%)	11 (44%)	2 (8%)	4 (16%)
Parents expect direct instruction	15 (62%)	3 (12%)	5 (20%)	2 (8%)
Testing and accountability requirements	7 (28%)	8 (32%)	6 (24%)	4 (16%)
Lack of funding or resources	9 (36%)	7 (28%)	8 (32%)	1 (4%)
Lack of PBL examples in subject area	7 (28%)	10 (40%)	6 (24%)	2 (8%)
Time to find, create or plan projects	5 (20%)	8 (32%)	7 (28%)	5 (20%)
Time to carry out projects	5 (20%)	7 (28%)	3 (12%)	10 (40%)

Lack of PD or coaching	11 (44%)	6 (24%)	6 (24%)	2 (8%)

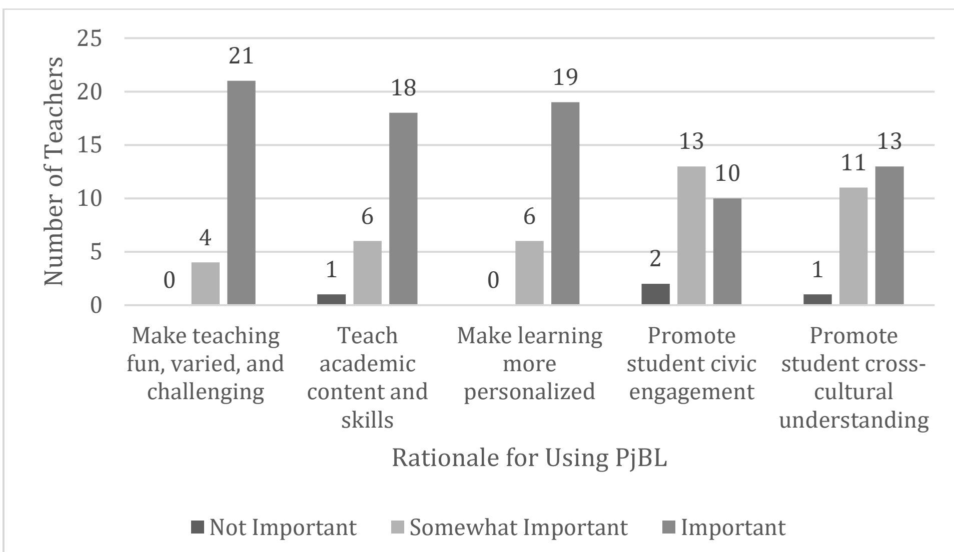
Minor challenges included attendance or student behavior (44%), too many students (40%), lack of PBL examples in the content area (40%), classroom space (32%), testing and accountability requirements (32%), finding time to create or plan projects (32%), and time to carry out projects (28%). Parent expectations for direct instruction (62%), lack of PD or coaching (44%), short class periods (40%), lack of funding or resources (36%), classroom space (32%), attendance and/or student behavior (32%), and lack of PBL examples in the subject area were most often identified as "not a challenge" (see Table 2).

Teacher Rational for Use of PBL

Figure 1 shows "important reasons" teachers selected for using PBL. Similar to other research (Bell, 2010; Hawkins, 2017) a strong majority of teachers' "most important" reasons included making teaching and learning more varied, challenging, or fun (21 *important* and four *somewhat important*); to teach academic content knowledge and skills more effectively (18 *important*, six *somewhat important*, and one *not important*); and to making learning more personalized and tailored to student individual interest or needs (19 important and six somewhat important).

Figure 1

Rational for Using PBL (n=25)



Other reasons for use of PBL included promoting student civic engagement (10 *important*, 13 *somewhat important*, and two *not important*) and promoting student cross-cultural understanding (13 *important,* 11 *somewhat important*, one *not important*. The questionnaire results suggest that teachers meet the Gold Standard PBL element of public view together with Gold Standard PBL teaching practices related to building culture, design and plan, and engage/coaching.

Use of Essential Project Design Elements and Project-based Teaching Practices for Gold Standard PBL

Table 3 shows Project Design Elements and Project-based Teaching Practices most often used by the teachers.

Table 3

Average Item Response by Element/Practice with Mean, Standard Deviations, Median and Modes (n = 25)

Practice	Element or Practice	Mean	SD	Median	Mode
Challenging problem or question [a]	1	4.36	0.82	5	5
Authenticity [a]	3	3.32	1.23	4	4
Reflection [a]	5	4.14	0.97	4	5
Public Product [a]	7	3.68	1.12	4	4
Design and Plan [b]	2	3.94	1.04	4	5
Align to Standards [b]	3	4.59	0.87	5	5
Assess Student Learning [b]	5	4.40	0.84	5	5
Scaffold and Student Learning [b]	6	3.14	1.00	3	3

Note. A 1-5 Likert Scale was used.
[a] Product Design Elements.
[b] Project-based Teaching Practices.

PBL Design Elements investigated included: a challenging problem or question, authenticity, reflection, and a public product. Challenging problems or questions along with reflections represent the project design elements used, to some extent, by the teachers. The mean for use of a *Challenging Problem or Question* was 4.36 and the median was 5 which suggests strong fidelity to this PBL element. A teacher commented about the purpose of driving questions in the PBL lesson. She said, "I think there's usually some kind of driving question. You could use the driving question to create a project and scaffold every day a little piece to the project." Challenging problems or questions are central to PBL (Krajcik & Shin, 2014; Larmer et al., 2015). These problems or questions are aligned to learning goals and are open-ended, allowing for more than one answer, in an effort to motivate the student. As this element is central to PBL, significant time was spent during preservice teacher training musing and reviewing first drafts initially by the university instructor and secondarily by an instructional coach.

The mean for *Reflection* was 4.14 and the median was 4 which again suggests the teachers used the element of reflection as an important part of the students experience with PBL. Reflection is integral to PBL as it deepens sensemaking and aids in the retention of learning and results in a higher-quality outcome. A teacher reflected about using PBL and stated:

> The hardest thing about PBL is that because the kids are discovering it on their own, they're not all gonna get it, you know? But it really does have to be a very intentional and its very time consuming, like, pre-loading type of thing that requires a lot, but I definitely think that it's worth the investment, even with testing.

As shown in Table 3, Gold Standards for project-based teaching elements were evident (Boss & Larmer, 2018; PBL Works, 2022). Three project-based teaching practices were frequently used: *Design and Plan, Align to Standards*, and *Assess Student Learning.*

The mean for *Design and Plan* was 3.94 and the median was 4 which suggests this teaching practice was an important component. Within the program, students are provided with extensive feedback involving critique and revision from the university instructor, content-area coach, and peers as they develop lessons that are aligned to standards and feature ongoing assessments. Each lesson must meet specified standards of quality before it is taught to students, and there is an emphasis on scaffolding to activate prior knowledge and connect to student interests (Arantes do Amaral et al., 2015; Gresalfi et al., 2012; Hmelo-Silver et al., 2007). The use of graphic organizers and the provision of examples, and learning progressions were used in the program to facilitate acquisition of content while attending to the needs of students (Grant & Branch 2005; Hmelo-Silver et al., 2007). In this questionnaire, every teacher indicated they used these practices to some degree in their classrooms. One teacher expressed, "I think that the teacher's job is to be very intentional in that, to make sure that they're guiding them. Every day it has to be a guided thing, and I think that people lose sight of what PBL is."

The mean for *Align to Standards* was 4.59 and the median was 5. Teachers are concerned with accountability. For this reason, aligning to standards provides the basis for the development of learning and is tied to evidence that learning is attained. One teacher described how important alignment to standards was in her school. She stated, "I will say that those testing pressures are very real, but I think that even just having one PBL project, is very worth it for the kids who experience taking something from beginning to end."

The mean for *Assess Student Learning* was 4.40 and the median was 5. As assessments provide evidence of what has been learned, they must be tied to standards and learning goals in ways that reinforce one another. The expectations for students must be clear to guide well-structured learning and monitor progress via use of assessment practices. An interesting example of formative assessment was described by a teacher while observing group work. She noticed some students were not contributing to the project, so she added a component for group members to evaluate one another. She stated, "So for them, I actually had them grade each other on that part for the equal amount of work and stuff, just to kind of see who they thought did the work and who they thought didn't, and they were very honest."

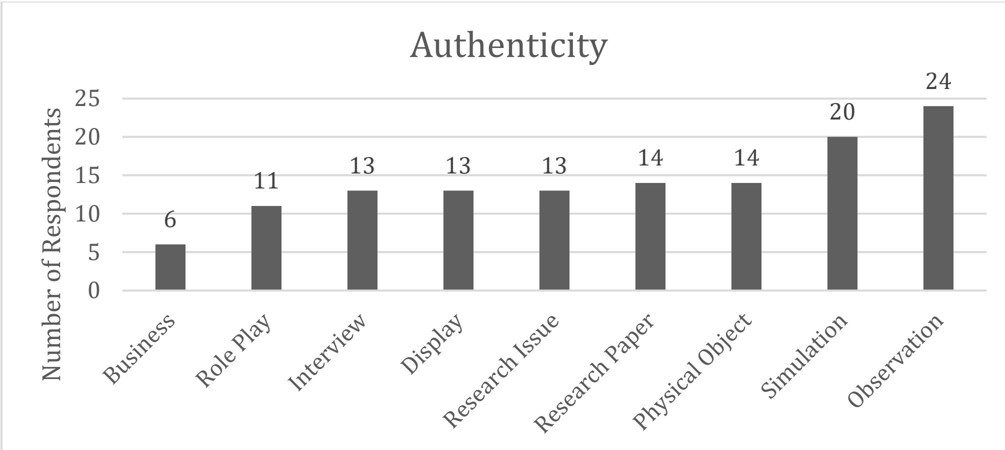
Authenticity

According to Parker and colleagues (2013), authenticity can be categorized as authentic to self (i.e., voice and choice, agency), or to others (i.e., public performance, products). Authenticity means engaging in projects that are real to the student or that impact the real world (Mann et al., 2020). That is, the project addresses a real need, the creation of a product, the setting up of a realistic simulation, or the use of scientific tools or processes. (Pepper, 2015).

For this study, simulation (80%) and observation (96%) were the types of experiences most often used to enact projects. See Figure 2 for this information.

Figure 2

PBL Gold Standard 3, Authenticity (n=25)



Approximately half of the teachers used the creation of a working prototype of a physical object/structure/device (56%), the presentation of research papers (56%) had students researching issues in the community (52%), display of artistic products/performances related to music, art, drama (52%), and interviewing family/community members to document experiences (52%). Role playing was also used to simulate solving of real-world problems (44%) as was simulation of running a business/service to the school or community (24%). One teacher described using PBL to teach different parts of the genetics lesson. She stated:

> One could be learning about fingerprinting and how everyone has their own fingerprint, and you know everyone has their own DNA, so you could teach them how to do fingerprinting. You could have someone who did fingerprinting for the police or something come in and teach them how to do it. You can bring in authentic audiences and stuff.

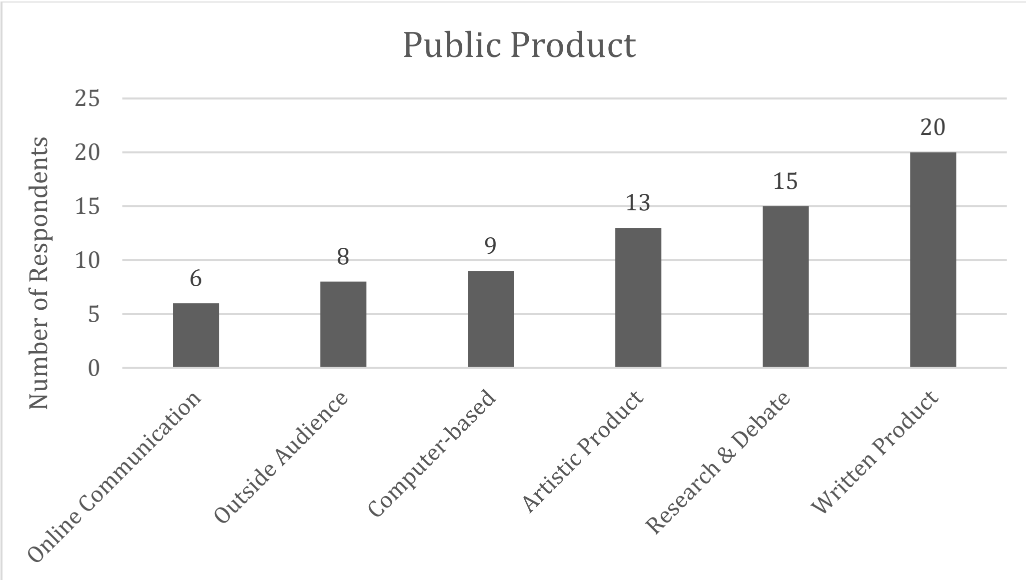
Public Product

Public Product and *Authenticity* are linked in the Gold Standard PBL Design Elements. By public audience, it is meant that the student applies what has been learned outside of themselves or outside of the classroom. This important aspect of PBL requires that students be given opportunities to discuss what they have learned as well as to discuss the processes with which they engaged in the during learning. This study supports the importance of a public product and has been cited by a number of researchers including Arantes do Amaral et al., (2015), Boss and Larmer, (2018) Grant, (2011), and PBL Works (2022).

In this questionnaire, the most common public product described by the teachers was the presentation of a written product (80%). Next in frequency were demonstrations of research and debate (60%) and artistic product/presentations (52%). Additional public products included computer-based artifacts (36%) presentations to audiences in other schools or professional experts (32%) and communicating via the Internet in various online applications (24%), as shown in Figure 3.

Figure 3

PBL Gold Standard Design Element, Public Products Used by Teachers (n=25)



Teacher Preparedness to Use Essential Product Design Elements and Project-based Teaching Practices for Gold Standard PBL

PBL requires multiple opportunities for the student to engage in sustained inquiry. Specifically, "Students engage in a rigorous, extended process of posing questions, finding resources, and applying information" (PBL Works, 2022). All teachers stated they felt *somewhat prepared* (11) or *well-prepared* (14) to promote depth or quality in student work during projects. As stated earlier, as part of their pre-service teacher training, a PBL unit was developed and implemented in a secondary school setting. This unit also aligns with CAEP accreditation artifacts, and as such, the pre-service teacher is provided with extensive feedback involving critique and revision during planning and design. Pre-service teachers practiced the lesson with a peer and a content area coach, and ultimately taught the lesson to public school students under supervision.

Sustained Inquiry, which is one of the essential PBL design elements, was stated as a challenge to implementation of PBL (Table 2), although the teachers indicated preparedness to have their students engage in a "rigorous, extended process of posing questions, finding resources, and applying information," as shown in Table 4.

Table 4

Average Item Response for Teacher Preparedness for Mean, Standard Deviation, Median and Mode

Practice	PBL Element #	Mean	SD	Median	Mode
Sustained Inquiry [a]	2	2.56	0.51	3	3
Design and Plan [b]	2	2.48	0.59	3	3
Design and Plan [b]	2	2.48	0.51	2	2
Align to Standards [b]	3	2.44	0.58	2	2
Manage Activities [b]	4	2.68	0.48	3	3
Manage Activities [b]	4	2.32	0.48	2	2
Assess Student Learning [b]	5	2.44	0.58	2	3
Assess Student Learning [b]	5	2.64	0.49	3	3

Note. n = 25; A 3-point Likert Scale was used (1 =not prepared; 2=somewhat prepared; 3=well-prepared).

[a] PBL Gold Standard Product Design Elements.
[b] PBL Gold Standard Project-based Teaching Practices.

That is, the teachers indicate they are prepared, but the challenges for implementation in the classroom are weighty due to challenges such as short class periods, student behavior, and lack of resources. As time is a variable that challenges implementation of PBL, it is possible that teachers have the expertise to facilitate inquiry, but feel they lack the time in the curriculum to do so. The mean score for teacher preparedness to promote sustained inquiry was 2.56 on a 3-point scale.

One of the Gold Standard PBL Teaching Practices is the *Design & Plan* of projects. As shown in Table 4 most teachers felt prepared to design and plan lessons, indicating they wanted to make teaching and learning more varied, challenging, or fun as well as create lessons to convey academic content knowledge and skills more effectively. Mean scores for two questionnaire items were 2.48 and 2.48 respectively with median scores of 3 and 2 respectively. That is, the teachers indicated they were prepared for *Design and Plan* PBL teaching practices. Two questionnaire items addressed preparedness to design and plan lessons (i.e., find existing project of high quality and plan and design new projects). When conducting projects, teachers developed a detailed overall plan describing the project from start to finish using artifacts such as templates, checklists, timelines, and project maps. However, novice teachers felt less prepared using PBL to meet district standards or state standards due to a school emphasis on benchmark and state testing (M = 2.44; Median = 2).

Teachers indicated they felt either *somewhat prepared* to *well-prepared* for the Gold Standard PBL Teaching Practice, *Manage Activities*. Two items addressed included promoting and supporting students' group work and structuring presentations in ways that encourage whole class learning. In particular, most teachers considered themselves well-prepared regarding the facilitation and management of students' work in groups (M = 2.68; Median = 3) and somewhat prepared in the creation of products made public (M = 2.48 Median = 2).

All participants indicated preparedness for the Gold Standard PBL Teaching Practice, *Assess Student Learning*. Three items addressed preparedness to assess content (M = 2.44; Median = 2) and assess group work. Rubrics were used to guide students and to assess projects for content accuracy, thoroughness, or depth of understanding. Formative assessment included short-term assessments such as *Just in Time Formative Assessments* (occurring in class that day), together with *Diagnostic Formative Assessments* (to identify student strengths and weaknesses) *and Medium-Cycle Formative Assessments* (i.e., project assessment, unit assessment).

Teaching Approaches Associated with PBL

There is a continuum of approaches with regard to the role of the teacher in PBL. Some aspects of instruction, such as the introduction to PBL may involve direct instruction, while other aspects are more oriented toward types of inquiry. Whichever approach is used, it should make the most of the learning time, removing bottlenecks to learning, allowing for differentiation, reflection, and sometimes just going with the flow (Boss & Larmer, 2018; PBL Works, 2022). The mean for a flexible approach was 3.63 with a median and mode of four while the mean for direct instruction was 3.16 with a median and mode of three. Specifically, fifteen teachers (60%) indicated they used a flexible approach *most of the time* or *all of the time*, while eight teachers (32%) used direct instruction *most of the time* or *all of the time*. Team teaching and interdisciplinary projects were *not at all* used or *sometimes* used. These practices suggest the teachers emphasized on the use of inquiry, but also used direct instruction as instructional models. This information is shown in Table 5.

Table 5

Average Item Response by Teaching Approaches Used with Mean, Standard Deviations, Median and Modes (n=25)

Teaching Strategy	**Mean**	**SD**	**Median**	**Mode**
Direct Instruction	3.16	0.80	3	3
Flexible approach	3.63	0.88	4	4
Team teaching	1.56	0.58	2	2
Interdisciplinary projects	1.76	0.66	2	2

Note. A 5-point Likert Scale was used (1=not at all; 2=sometimes; 3=half the time; 4=most of the time; 5=all the time).

Conclusions

PBL has been shown to develop critical thinking skills, promote deep learning, and encourage self-directed learning (Larmer, 2015). Additionally, the use of PBL has been shown to enhance collaboration, motivation, integration of knowledge, and the preparation of the student for real-world challenges (Larmer, 2015). Instead of focusing on rote learning and memorization, the learning shifts to understanding and the application of knowledge though a process of self-directed learning. Such experiences should better prepare students for the job market though encouragement of creativity and innovating to promote economic growth and meeting local and national challenges. For this reason, this program and other UTeach replication programs across the United States have as a part of the curriculum a course in PBL that includes not only classroom instruction, but also extensive field experiences in schools that utilize PBL. Within this model, instructors act as facilitators and feedback, most notably a recursive cycle of reflective practice is common.

This study examined secondary science and mathematics teacher knowledge of and beliefs about PBL design elements and teaching practices. Of 96 respondents, 25 teachers completed the questionnaire and indicated they used PBL as an approach to learning. Response to the questionnaire was good with 96 out of 138 responding. Still, the frequency of PBL use in the classroom (25% or less of instructional time), school district support for PBL (half-day or less of professional development) and the number of respondents who used PBL in their classroom (26%) is disappointing given the 70 hours of instructional time dedicated in the course. More so as it is a core course, as well as the significant field experiences that took place in PBL settings the use of PBL in the classroom is underwhelming. Also, 76% of teachers indicated they work in schools that emphasize 21st century skills, so it is unclear what other approaches are used to acquaint students with these skills.

The rationale for use of PBL (i.e., fun, teach academic content, teach 21st century skills) and the challenges associated with its use (i.e., funding, accountability requirements, time constraints) echo that of previous researchers. However, we found teacher beliefs about the effectiveness of PBL to teach low-achieving students was contrary to research findings which show PBL to be at least the same as other approaches with regard to achievement. It is interesting that the teachers agreed that PBL helped with motivation and with students who have limited English skills.

With regard to preparedness to teach PBL, the teachers indicated they felt *somewhat* or *well-prepared* to use the Gold Standard PBL design elements and teaching practices. Results showed teachers believed they were prepared to use sustained inquiry (i.e., promote depth and quality), authenticity (i.e., observation, simulation) assessment (i.e., individual and group assessment), design/plan (i.ge, find high quality projects, plan/design new projects), manage activities (i.e., group work, class presentations) and facilitate public presentations outside the classroom (e.g., I*EARN, Project Globe, performance, brochures). Given the prior experiences as pre-service teachers, those teachers using PBL demonstrated good knowledge of the Gold Standard Design Elements and Teaching Practices.

Implications

Secondary mathematics and science teachers in this study displayed knowledge of the Gold Standard Design Elements and Teaching Practices of PBL and indicated they felt prepared, to some extent, to facilitate PBL in their classrooms. A majority of the teachers used inquiry as well as direct instruction as dominant models of teaching within PBL and emphasized their belief that flexible instruction is important to achieve fidelity to the approach. However, in this study, only about 25% of the total respondents (n=93) indicated they used PBL in the classroom, and 68% of these teachers (17/25) used this approach less than 26% of their instructional time.

PBL is a core course in UTeach replication sites across the United States (>50 sites). More research into the comparison of various programs graduate's use of PBL in their classroom once they become classroom teachers is also warranted.

Limitations

Compared to other programs in the United States, this program is among those producing a large number of high-quality mathematics and science teachers who have been well prepared in both content and pedagogy. However, compared to the need for high-quality teachers, these numbers are inadequate. Marder (2020) and also Landa (2024) addressed the inadequate teacher pipeline. Thus, while this study represents a large program in the United States, the sample is small but remains an important research setting.

Although challenges to implementation of PBL were identified by the teachers, more research is needed to fully understand the challenges that prevent teachers from spending time using this approach to its fullest potential. In addition, more research is needed to address questions such as: "At what point do teachers believe classes are too large to implement PBL? How can the negative role of accountability requirements be addressed? When and what ways should students acquire skills to take full advantage of PBL?"

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"Covid-19 Pandemic" As a Controversial Social-Scientific Issue: Teachers' Beliefs and Informal Reasoning

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ABSTRACT

The main purpose of this study is to examine the epistemological beliefs and informal reasoning of science and social studies teachers about Covid-19, which is a controversial socioscientific issue. Qualitative research, specifically phenomenological design, was used in the study. During the data collection process, teachers' epistemological beliefs, reasoning skills and perceptions of Covid-19 were elicited using the Semi-Structured Interview Protocol (SSIP) developed by the researchers. Categorical analysis, a type of content analysis, was used in the examination of qualitative data. As a result of the research, it was found that teachers' epistemological beliefs about Covid-19 are formed in order to define and explain the source of this information. In contrast, it was found that while the most common sources of information about Covid-19 are the internet, the environment, and intuition, the least used source of information is scientific publications. Teachers failed to provide sufficient evidence to substantiate their claims and found it difficult challenging scientific arguments to bolster their own opinions. Science teachers believe that the main purpose of teaching social science issues is to develop scientific process skills. Social studies teachers believe that the main purpose is to develop a sense of citizenship and the thinking and decision-making skills that individuals need to solve social problems.

Keywords: beliefs, Covid-19 pandemic, controversial issues, teachers.

Introduction

Individuals face many controversial issues in society and need to make decisions on these subjects. Some of these controversial subjects include a scientific dimension. Such subjects are characterized by the expression of very different opinions and the inability to reach a definitive conclusion (Sadler & Donnelly, 2006; Topcu et al., 2010). For this reason, such subjects are referred to as controversial social-scientific issues. Socioscientific issues (SSI) are scientific topics that are "based on scientific concepts or problems, are controversial in nature, are discussed in public environments, and are frequently subject to political and social influences" (Sadler & Zeidler, 2005, p. 113). In order to make effective decisions on these subjects, individuals need to produce arguments and use scientific knowledge in discussion environments about them (Lee & Grace, 2012). In this case, science literacy appears as a prerequisite. For this reason, in the reforms carried out in many different countries in recent years in the field of science education, it has been emphasized that students should be scientifically literate, and regulations have been made for this purpose (American

Association for the Advancement of Science, 2000; Australian Curriculum Assessment and Reporting Authority, 2015; Rennie et al., 2001; MoE, 2018). The main purpose of science teaching in the international arena today is to enable students to understand and make decisions about the events around them from a scientific point of view. There are different definitions of scientific literacy in the literature. In this study, scientific literacy is defined as being able to recognize, understand, and interpret scientific knowledge, to question events in everyday life and to view these events from a scientific perspective.

Many studies state that the use of SSI contributes not only to the science literacy or cognitive development of students but also to their social and emotional development. The first changes related to science education in Turkey started in 1992 under the name of the Science-Technology-Society (STS) approach, and SSI were directly included in the science education program in 2013 (MoE, 2013). In the 2018 program update, science education was founded on the Science-Technology-Engineering-Mathematics (STEM) approach. Again, this update aimed to develop students' reasoning ability, scientific thinking habits, and decision-making skills using sociological topics (MoE, 2018). Therefore, in recent years, SSI has become an important part of both the science curriculum and the research topics of science teaching.

While science and technology constitute one dimension of SSI, the other important dimension is the social dimension, including ethical, political, moral, religious, personal, and social values. If there is also a scientific dimension in these social subjects, then it is expressed as SSI (Sadler, 2004). Therefore, global climate change, alternative energy, environmental subjects, hydroelectric power plants, cloning, and biotechnology are the most well-known socioscientific issues. These subjects also have an important place in the ethical and social dimensions of citizenship and social studies education. What is expected from students today is not being those who memorize the given information and answer when asked, but being those who are researching, questioning, discussing, and producing. SSI contributes to the development of higher-order skills, improves beliefs about the nature of science, increases ethical and moral sensitivity, and develops citizenship skills (Barrue & Albe, 2013; Ratcliffe & Grace 2003). Since these subjects are directly related to society, it allows individuals to be sensitive and responsible individuals for social subjects.

All these mentioned skills are also the qualities that a citizen who wants to be raised in a democratic society should have. Social studies aim to develop the knowledge and citizenship competencies necessary for students to be active and participate in public life. Citizenship competence is based on a commitment to democratic values and requires the ability to use knowledge, inquiry, and problem-solving skills about one's society, nation, and the world. Knowledgeable, talented, and democracy-committed young people are necessary to maintain, develop our democratic lifestyle, and become a member of the global community (National Council for the Social Studies, 2010, p. 2). Through SSI, students learn to be active and informed participants in society (Reis & Galvão, 2009). Several authors have argued in terms of citizenship, decision making, and democratic participation in teaching the nature of science (Driver et al., 1996). As Solomon claims (1994), the highest aims of Social Studies teacher (STS) education relate to how our students will behave as citizens. Social-scientific subjects could feature under any of the three headings: citizenship, scientific literature, sustainable development (Ratcliffe & Grace, 2003).

Epistemological Beliefs and Informal Reasoning Regarding SSI

Due to the fact that sociological subjects contain controversial and complex problems, the process of informal reasoning can create an appropriate environment for discussing and trying to solve such subjects (Topcu, 2017). Informal reasoning is described by Zohar and Nemet (2002) as involving reasoning about causes and consequences and about advantages and disadvantages, or pros and cons, of partial propositions or decision alternatives. In the SSI discussion process, producing arguments in order to support the claims put forward and rebut the objections and approaching a socioscientific subject from multiple perspectives improve informal reasoning (Sadler & Zeidler, 2005; Wu & Tsai, 2007; Zohar & Nemet, 2002). The informal reasoning process emerges whether the factors affecting the individual's decision are their own interests, the society they live in, all other people, their religious beliefs, political views, economic, scientific developments, or ecological concerns. In addition, whether there is an emotional, rational, or intuitive approach to the socioscientific subject emerges in the process (Elvan, 2020).

Research has shown that one of the most important factors influencing informal reasoning is epistemological beliefs. Epistemological beliefs include beliefs about the definition, creation, evaluation and status of knowledge (Hofer, 2001). Personal epistemology is a multifaceted concept that primarily reflects an individual's "beliefs about the nature of knowledge and the processes of knowing" (Hofer & Pintrich, 1997). It has been argued that individuals may hold epistemological beliefs about the certainty, source, justification, acquisition, and structure of knowledge. These different dimensions of knowledge have led researchers to define epistemological beliefs from a multidimensional perspective (Yılmaz-Tuzun & Topçu, 2008). Teachers' beliefs about the nature of science have a significant impact on their teaching style, assessment methods and lesson planning. A positivist approach sees the role within the classroom as primarily one of transmitting knowledge to students, whereas a constructivist approach encourages students to actively construct knowledge themselves. This orientation determines whether the lesson is teacher-centred or student-centred. While a positivist teacher believes that students should passively receive knowledge, a constructivist teacher encourages students to actively engage in the construction of knowledge. Positivist teachers are often perceived as authoritative figures who impart correct knowledge, whereas constructivist teachers have more egalitarian relationships with students and encourage active exploration of knowledge. Sadler et al. (2006) reported that some teachers saw SSI as important subjects to deal with, so they preferred student-centered activities where students could share their ideas and tried to provide a classroom environment. However, some teachers believed that science teachers were responsible for teaching scientific facts, and they did not have to deal with ethical or moral concerns, which were part of SSI. Therefore, they designed their lectures mostly teacher-centered. Teachers, educators, and researchers claim that teachers' beliefs shape their approach and practical theories in classroom teaching, influencing their instructional strategies and performance in the classroom (Cheng et al., 2009).

Covid-19” As a Controversial Socioscientific Subject

Socioscientific subject contexts can be classified as national, local, or global. The new type of coronavirus (Covid-19), which first appeared in China in the last months of 2019, affected the whole world by transforming into a global pandemic quickly. Several pandemics, such as H1N1, Asian Flu, and Spanish Flu, have occurred before, but none have spread so widely and confined to specific regions or continents. Depending on the technological and economic developments, human mobility has increased, and the pandemic spread rapidly in a short time. Everyone became interested in Covid-19 as a socioscientific topic due to its immediate and deadly impact. Throughout this process, all countries have taken various measures to prevent the pandemic from spreading further. Public discussions have focused on many of these measures. Public demonstrations protested the strict measures taken in many countries, including Germany, Italy, England, Brazil, the USA, Canada, Australia, and New Zealand. Until now, no socioscientific subject, including global warming or other environmental problems, has affected the whole world in such a short time.

Covid-19 meets all the criteria of a socioscientific subject. Because it includes a scientific and technological dimension, it is widely discussed by society, and also the ethical, political, social, and economic dimensions of this subject are included. For example, the emergence of Covid-19, the process of its spread, the measures taken, and the discussions during the vaccine development process draw attention to their scientific and social aspects. Thus, Covid-19 is a rather important socioscientific subject that can be addressed in both science and social studies classes. Covid-19 has been selected as a socioscientific topic due to the fact that it is a current topic in this study.

Previous research

Examining previous studies on SSI reveals a primary focus on students and teachers within the science course. Research on students about SSI includes studies on the impact of SSI on students' attitudes towards science lessons (Ottander & Ekborg, 2012; Ritchie et al., 2011), as well as studies on enhancing students' knowledge and argumentation skills (Dawson, 2015; Dawson & Carson, 2017; Dawson & Venville, 2010; Wu & Tsai, 2007; Yang & Anderson, 2003; Zohar & Nemet, 2002). Studies on teachers about SSI encompass subjects like teachers' beliefs and arguments (Ekborg et al., 2013; Liu & Roehrig, 2019), as well as the perception, competencies, and informal reasoning of teacher candidates (Choi & Cha, 2018; Lee et al., 2006; Robertshaw & Campbell, 2013). On the other hand, research on SSI in the field of social studies is limited. However, recent studies have observed the use of SSI in social studies (Elvan, 2020) and the teaching of citizenship subjects (Barrue & Albe, 2013; Lee et al., 2013). However, no comparative studies have been conducted on Covid-19, a current topic in SSI. The main purpose of this study is to examine the epistemological beliefs and informal reasoning of science and social studies teachers about Covid-19, which is a controversial socioscientific subject. This research seeks answers to the following questions:

RQ1. What personal epistemology do teachers hold about the Covid-19 pandemic?
What are the beliefs developed in:
- RQ1.1. the structure of knowledge?
- RQ1.2. the source of knowledge?
- RQ1.3. the stability of knowledge?

RQ2. What are the teachers' views on the teaching process of social-scientific subjects?

Methods

Research Design

This qualitative research study used phenomenology design. The phenomenology design examines events, experiences, perceptions, orientations, and situations in the universe that we are aware of, but lack a deep and detailed understanding of, and that we can observe directly or indirectly (Creswell & Poth, 2016). The study considered the Covid-19 pandemic as a phenomenon and aimed to reveal teachers' beliefs, perceptions, and meanings associated with it.

Participants and Procedure

Homogeneous sampling, one of the purposive sampling methods, was used in the creation of the study group. By choosing a purposeful sampling method, it was possible to study the Covid-19 phenomenon within the scope of the study in-depth, and the diversity of the participants associated with the problem of the study was reflected as much as possible in a relatively small sample (Creswell & Poth, 2016; Patton, 2014). In this process, the study group was determined to consist of similar, variable, and different situations related to the problem. In this context, a study group consisting of a total of 14 people, seven science and seven social studies teachers, was formed in the context of gender, seniority, school location, and education level difference. Within the scope of the study, the researchers tried to find out whether there were common or shared cases that vary, and aimed to examine the different dimensions of the research problem depending on this diversity (Marczyk et al., 2005). Demographic information for study participants is available in Table 1.

Table 1

Demographic Information of the Teachers in the Study Group

Participant	Branch	Gender	Seniority	Education level
SE1	Science	Male	7	Master
ST2	Science	Male	11	Bachelor
ST3	Science	Male	13	Bachelor
ST4	Science	Male	8	Bachelor
ST5	Science	Female	18	Master
ST6	Science	Female	9	Bachelor
ST7	Science	Female	5	Master
SST1	Social Studies	Male	9	Bachelor
SST2	Social Studies	Female	5	Bachelor
SST3	Social Studies	Male	5	Master
SST4	Social Studies	Male	14	Bachelor
SST5	Social Studies	Male	18	Master
SST6	Social Studies	Female	9	PhD
SST7	Social Studies	Female	9	Bachelor

A total of 14 teachers, including seven science and seven social studies teachers, are included in the study sample. While eight of the teachers are male, six of them are female. In general, the seniority of teachers ranges from five to 18 years. Two of the teachers in the study group work in the village, five of them work in the district, and seven of them work in the city center. In addition, eight teachers have bachelor's degrees, while six teachers have graduate degrees.

Instrumentation

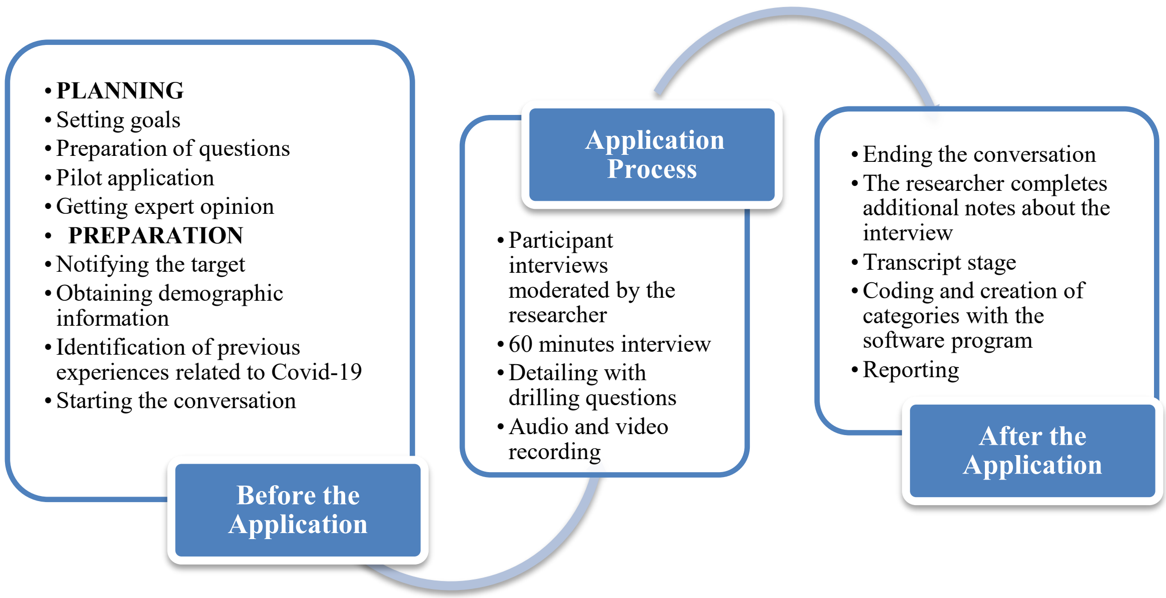
In the data collection process, the "Semi-Structured Interview Protocol" (SSIP) developed by the researchers was used to determine the epistemological beliefs, informal reasoning, reasoning skills, and perceptions of teachers about Covid-19. SSIP was used as the main data collection source in the research. During the development of the draft measurement tool, a total of nine questions were prepared in the context of Schommer's (1990) Multidimensional Epistemological Belief System, and the opinions of two experts were sought. In this process, the opinions of the experts for each item were taken in the form of "usable," "usable after correction," and "unusable" triple Likert for each item. In accordance with the feedback from the experts, two questions were combined with other questions contained in the draft interview form, and additional questions were added to the questions. The inter-assessor Cohen Kappa coefficient of agreement of the SSIP, which consists of seven questions in its final form, was calculated as .76. This result can be interpreted as the interview form will give reliable results in the study.

Data Collection Process

Interviews with teachers were conducted under the moderation of the researchers. In addition, the interviews were videotaped. This process aims to prevent the factors that are thought to cause mistakes in the interview process, such as the researcher's bias, directions, and subjects that are not emphasized. In addition, the internal reliability of the study could be increased in this way. The procedures related to the operations before, during, and after the interview are summarized in Figure 1 step by step.

Figure 1

Symbolic View of the Application Process



Before the Application

Pre-application of the research was structured in two dimensions. In the planning phase, the study's aims with the research team were clarified, the topic of Covid-19 was chosen as the research topic, SSIP was developed accordingly, expert opinion was taken, and a pilot application was made. SSIP was applied to a teacher who was not in the study group at the pilot application stage. This process aimed to see possible risks/deficiencies such as time management, organization of the online meeting environment, determining the meeting time, internet interruption, video-sound quality, video-audio recording process, and to produce possible solutions.

In the second dimension of the pre-application period, preparatory studies were carried out. In this process, the teachers were informed about the subject, their demographic information was obtained, their experiences before the interview about Covid-19 were tried to be determined, and information was given about the interview process.

Application Process

The study team, consisting of two moderators and a teacher, carried out the application process and conducted an online interview. While one of the study team's researchers conducted the interview as the main moderator, another researcher made observations to prevent the discussion of unrelated subjects and to ensure the recording process was completed and checked.

The application process was limited to a total of seven questions in a period of 45-60 minutes, and drill questions were asked for detailed purposes. During the interviews, teachers were asked to express themselves in a democratic process in a way that would allow them to express their epistemological beliefs and informal reasoning about Covid-19.

After the Application

This phase covers the processes in which teachers' statements are evaluated through interviews. In this process, the stages of the researcher completing the diary-style additional notes about the interview, the transcription of the audio recordings, the categorical analysis of the qualitative data obtained with the MAXQDA program (theme-category-code), and the reporting of the data were carried out.

Data Analysis

In the analysis of the obtained qualitative data, categorical analysis, one of the content analysis types, was used. Categorical analysis generally refers to dividing a particular message into units and then grouping these units into categories according to certain criteria (Bilgin, 2000). The stages of the qualitative data analysis process are listed below.

- Transcript stage*:* The audio recordings obtained within the scope of the interview were transcribed sentence by sentence to reflect the expressions in the original audio recordings. In addition, the additional notes of the study team about the interview were associated with the relevant parts of the transcripts.

- Coding phase with inductive paradigm: In the study, the data were first coded and turned into meaningful wholes with inductive analysis. In this process, the aim was to try to reveal the concepts underlying the data and the relationships between these concepts.

- Category creation stage*:* The data obtained in the coding process were divided into meaningful sections (one word, one sentence). The aim of this process is to divide the observation and interview texts into sections, to examine, compare, conceptualize and associate them. Then, commonalities between the codes were tried to be found and categories were formed by bringing them together. In the thematic coding process, it was aimed to determine the similarities and differences of the qualitative codes obtained and to determine the themes that can bring together the codes that are related to each other accordingly. In this process, categories were formed by finding the commonalities between the codes related to teachers' epistemological beliefs.

- Reliability phase*:* In this process, codes were gathered under themes by two different researchers and the inter-rater agreement coefficient was determined. According to Miles and Huberman's (1994) disagreement-agreement principle, the inter-rater agreement was calculated as .92. This finding shows that the internal reliability of the data is highly consistent.

- Reporting stage: Categories were determined, meaning units or items were placed in these categories, and their frequencies were determined. In this process, intensity and importance were determined for the categories.

- Quoting from original texts*:* In order to increase the internal reliability of the obtained data, the obtained data are given in the findings in the form of direct quotations. In this process, “ST” was used for Science teachers, “SST” was used for Social Studies teachers, and numbers were used for teacher order.

Limitations of the Study

This study is limited to the responses of a total of 14 teachers, seven social studies and seven science teachers, to the semi-structured interview form regarding the Covid-19 pandemic.

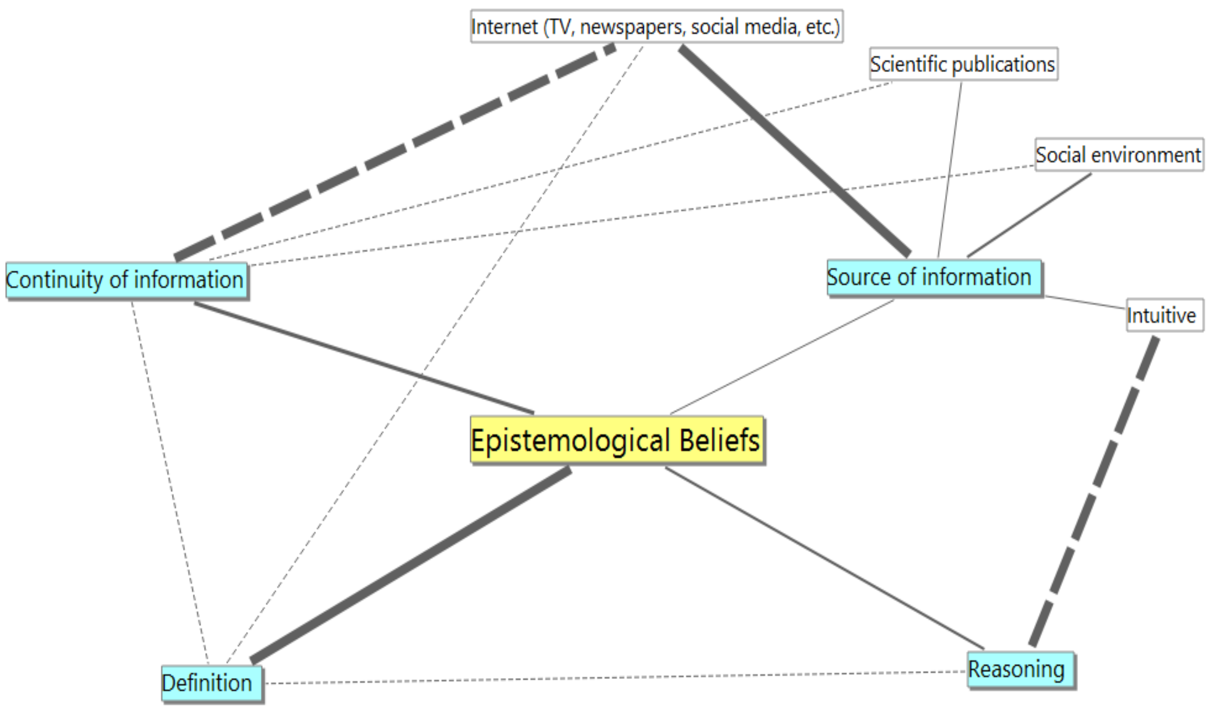
Findings

Epistemological Beliefs

The categories and subcategories formed for teachers' epistemological beliefs and the relationship between them are summarized in Figure 2.

Figure 2

Categories of Epistemological Beliefs



As seen in Figure 2, teachers' epistemological beliefs were mostly formed in a way to explain the definition and the source of this information. In the category of the source of information, the codes are collected under four subcategories: internet (TV, newspapers, social media channels, etc.), environment, intuitive and scientific publications. The least codes are included in the categories of reasoning and effects.

When the relational codings were examined, while related codes were formed between the source-intuitive subcategory of knowledge and reasoning, related codes were formed between the continuity of knowledge and the internet (TV, newspaper, social media channels, etc.), environment, and scientific publications subcategories. However, there is a relationship between the continuity of information and the internet (TV, newspaper, social media channels, etc.). In addition to these, related codes have emerged between the categories of continuity of information and changeability of information.

Definition

Examining the definitions of Covid-19 reveals two distinct perspectives. According to the widely recognized definition, Covid-19 is classified as a pandemic disease. All teachers who identified it as a pandemic disease also identified Covid-19 as a virus.

The second definition of Covid-19 does not incorporate any health-related concepts. In this definition, Covid-19 has been defined as a reaction of nature, a conspiracy theory, an interstate show of power, a disaster, a process of unity, or a change of habits. One of the important points in the definition is that all the science teachers emphasized it as "*a virus*" when describing Covid-19. While a few of the social studies teachers emphasized it as a virus, others defined it as a "process" with its effects. For example, ST3 defined it as "a virus that looks like flu but shows its effects in different ways according to the immune system of the person and for example, according to chronic diseases", while SST2 defined it as "Covid-19, a process that reveals how important social relations and health are, and how important education is."

The Source of the Information

The codes collected under the category of the source of information were collected under four subcategories. These are the internet (TV, newspaper, social media channels, etc.) (40), environment (experience) (16), intuitive (9), and scientific publications (4) subcategories. In this process, the main sources of information for teachers are the resources they accessed via the Internet and mainly social media tools. On the other hand, it can be said that the statements of the minister of health are mainly followed through Internet resources, followed by some social media, Internet news, and column articles. Among the internet resources, only SST7 and ST1 emphasized academic articles. For example, ST7 said, "Sometimes, I also get information from the articles I read during my own research. The information provided by a scientist can sometimes be consistent with the information provided by another colleague. But sometimes, it can also be contradictory. This leads me to do more research on topics I am interested in."

In addition, some teachers especially think that information sources do not provide accurate information and are skeptical. For example, ST2 stated "I have some doubts about the information I obtained from the Internet, but there is no certainty before or during this process." When the answers in the subcategory of the environment (16) were examined, it was determined that the teachers had information about Covid-19 through the information they obtained from their neighbors, the events experienced by their relatives, and the people around them, and their friends. As an example, ST3 made a statement, "I have that information from people living in my neighborhood, people who have survived Covid-19 or people they know at work, through what we heard from them."

On the other hand, some teachers used intuitive (9) expressions when describing Covid-19. In this process, they stated that "they believed that their explanation was like this," and they did not have a source for this information and had not read a scientific publication. These findings indicate that some teachers approach the information acquisition process intuitively and do not feel the need to access the content of a scientific article/publication related to it. In fact, scientific publications (4) are the least emphasized subcategory in the subcategory of the source of knowledge.

Continuity of Information

Two subcategories arise under the category of continuity of information (19). These are certainty (15) and doubt (4) subcategories. Predominantly, teachers believe that the statements of official institutions such as the World Health Organization, the Ministry of Health, the Scientific

Council, the scientists, or the health professionals in their immediate surroundings are "accurate information." On the other hand, some teachers have expressed that they have to believe the statements of these institutions. As an example, ST3 expressed that "This information is entirely information that we obtain from the ministry of health or members of the scientific committee. I believe in its accuracy, I trust the scientific committee." A few teachers stated that the information they obtained was not certain, there were contradictions in this information, and they doubted this information. Teachers especially expressed that they were suspicious of the information they obtained from the internet.

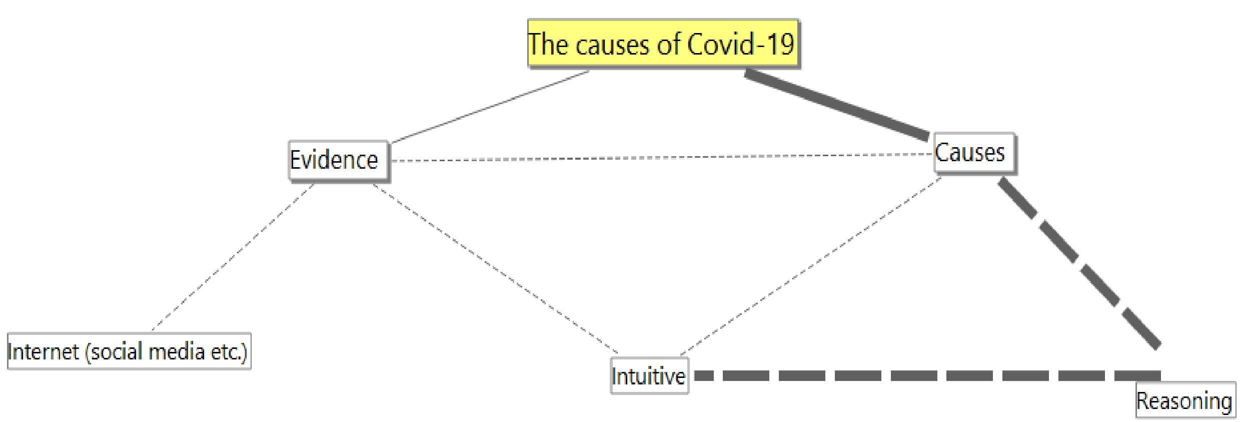
Participating teachers do not find the statements of policymakers reliable. Teachers have stated that politicians have very different goals, that their main goal is to maintain their power and show strength, that they are fighting to prevent the economy from being negatively affected, and that politicians all over the world are aiming for certain interests. Some teachers stated that it was not right for politicians to be so prominent during this process. They did not take their discourses into account and created distrust with contradictory statements. Some teachers stated that they follow the minister of health in Turkey because he is a scientist. In this regard, for example, STT2 stated the following: "Some things lose their credibility when they go together with politics. I don't believe in politicians anyway, so I think there's no credibility in politicians' policies either." The majority of the participating teachers emphasized that even if they have different discourses, they find scientists reliable because they have no interests and that they follow their explanations, but that scientists may be under pressure in some cases. In this regard, for example, SST3 stated: "I think the scientist thinks universally and humanistically. I trust the scientists, but that's not 100 percent."

Causes of Covid-19

As can be seen in Figure 3, the evidence for Covid-19 is that teachers mostly explain it with intuitive answers. In this process, the source of their information is mostly based on the reasons they obtained through the internet (social media, etc.).

Figure 3

Categories Related to the Causes of Covid-19



Causes

The causes category is grouped under two subcategories, *natural* and *artificial*. All of the teachers who believed that Covid-19 emerged naturally emphasized that this virus emerged in China and was transmitted from an animal to a person. Teachers who have this thought believed that the main reason for human transmission was the result of an unhealthy diet in China, not paying attention to cleanliness and hygiene, not taking the necessary precautions, and not giving information to the world. A few teachers, who thought that it emerged naturally, stated that they thought this virus was a result of people harming nature for years, and that they thought it was a reaction of nature. Teachers who believe that Covid-19 was created artificially, on the other hand, claim that this virus was produced in a laboratory environment for various reasons. It is seen that there are mainly social studies teachers in this thought. These teachers stated that they believed that the virus was produced in a laboratory environment for a biological warfare purpose, that many things were wanted to be tested in the international arena for this purpose, and that some states were engaged in power wars. For example, SST2 expressed an opinion on this subject: "First of all, I think that Covid-19 is an artificial virus produced in a laboratory environment."

Evidence

Almost all of the teachers who expressed their opinions about the emergence of Covid-19 did not reveal any scientific evidence for the reasons they put forward. Teachers who believed that Covid-19 emerged naturally cited sources of information (internet, news, etc.) as evidence. On the other hand, a few science teachers claimed that the virus multiplies in dirty and unhealthy environments. This information is included in textbooks or scientific articles, so these are scientific proofs. Teachers who believe that Covid-19 emerged artificially, on the other hand, stated that it is intuitive or logical as evidence, and they do not have any scientific evidence other than that.

Results of the Covid-19 pandemic

As can be seen in Figure 4, while the responses were mainly positive in the environmental and scientific categories, they were negative in the social/psychological, political, education, health and economic categories. These findings show that especially teachers think that positive results have emerged in the context of the results of Covid-19 as well.

Social/Psychological

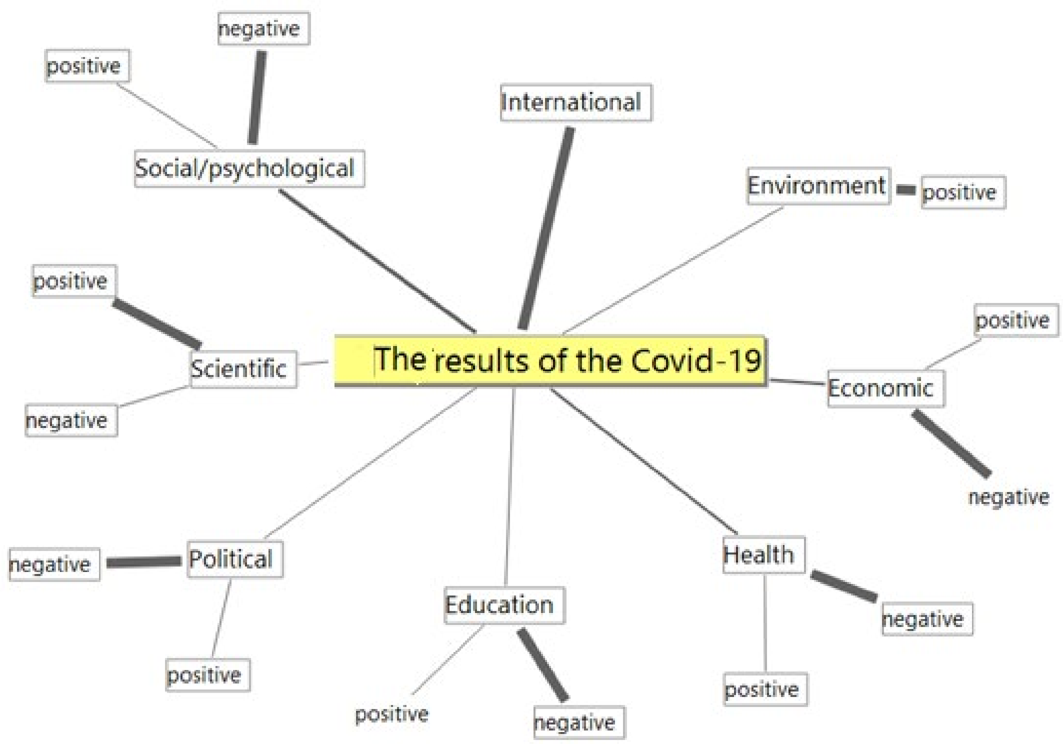
Teachers gave opinions about the social/psychological results of Covid-19 in two subcategories as *negative* (47) and *positive* (7). Teachers who expressed a negative opinion stated that the pandemic caused many psychological concerns in individuals and, therefore, in societies. Teachers have said that they have experienced many complex emotions with the pandemic, such as fear of losing loved ones, anxiety about the future, fear of loneliness, obsession with cleanliness, insecurity, and anxiety. Teachers stated that they did not know how the Covid-19 virus spread and that scientists' explanations significantly impacted their psychology. On the other hand, some teachers emphasized that the pandemic also had positive results in the social field. These teachers said that with the pandemic, their family members came together, and they could spend more time together

Economic

Teachers gave opinions about the economic results of Covid-19 in two subcategories as *negative* (43) and *positive* (11). In the economics category, both science and social studies teachers emphasized the adverse results of the pandemic on the national and global economy. They emphasized that people lost their jobs on a national scale, tradespeople closed their jobs, the industry came to a standstill, and the tourism sector was adversely affected. By drawing attention to the adverse results of the pandemic on a global scale, teachers stated that the worldwide economy was adversely affected, the supply chain was disrupted, countries had to print money, and this situation caused severe inflation. On the other hand, some teachers have noted the positive results of the pandemic on the economy. The teachers who expressed their opinions on the positive results drew attention to two points. One of them is savings, and the other is the digitalization of trade. Regarding savings, teachers have noted that people were necessarily turning to savings, reducing their unnecessary consumption. Some teachers have pointed out that people were necessarily turning to online commerce and that the digitalization that can be experienced in the ten-year process is experienced in 1 year.

Figure 4

Categories Related to the Results of the Covid-19 Pandemic



Education

Regarding the results of Covid-19 on education, negative (64) and positive (18), teachers expressed their opinions in two subcategories. It was observed that a large number of opinions have been expressed regarding the closure of schools and the distance education process. The teachers stated that the consequences of the schools being closed would be very severe, that the children were affected psychologically very negatively, and that many new problems emerged with the online education process. Regarding the online education process, they stated that the country's infrastructure, teachers, and students were not ready for this subject. Teachers emphasized that quality access could not be provided due to the lack of infrastructure. A quality teaching process was not experienced due to teachers' lack of digital competence, and students did not have the digital tools and access due to inequality of opportunity. Many students could not attend the lesson. It has been stated that there are different problems with students who have digital access. Many of them have increased digital addictions, a quality teaching process cannot be carried out, they cannot follow the students, and assessments and evaluations cannot be made. ST6 stated the following on this subject: "On the one hand, we do not have an adequate infrastructure as National Education; on the other hand, students do not have enough opportunities. Therefore, the education sector has experienced a great deal of hardship and is still experiencing it."

Teachers, who stated that Covid-19 had positive (18) effects on education, stated that a revolution was experienced in education without taking time and space into account. In this process, teachers emphasized that the digital competencies of educators developed rapidly, countries accelerated their infrastructure activities in this field, that digitalization, which can be experienced in a very long time, is experienced in a short time in the field of education, and that digital contents and research in this field have increased.

Environment

It is seen that teachers only gave *positive* (14) opinions regarding the results of Covid-19 on the environment. The teachers who participated in the research pointed out that the environment was relieved when people were closed to their homes. The damage caused by human beings to the environment in this process was minimized. The teachers stated that the factories were closed, the vehicles were not on the road, people did not go on vacation, the seas were cleaned, and nature had a chance to renew itself. Regarding this subject, SST1 stated that:"... There have also been positive results. Nature took a breather because people were at home. For example, air pollution decreased because there was no traffic."

Other

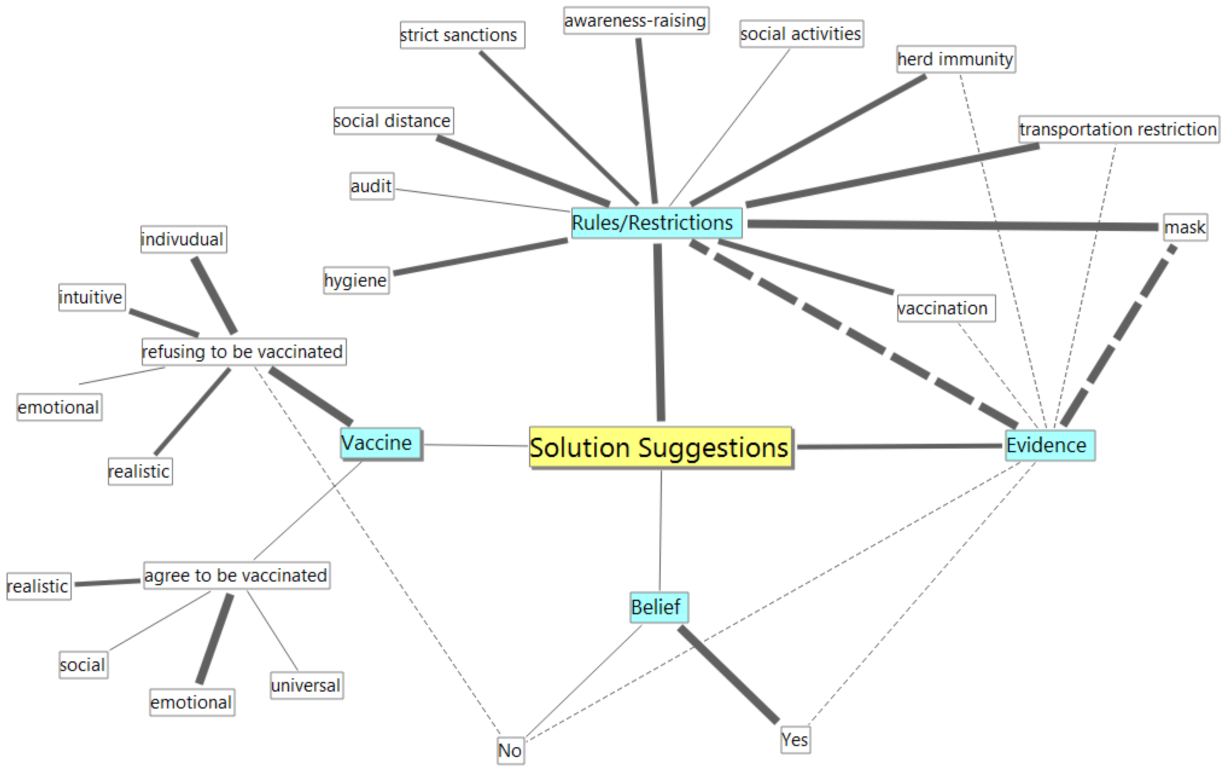
Some teachers drew attention to the results of the pandemic on politics, science, and health. A few social studies teachers stated that with the pandemic, the power of governments had increased worldwide, personal rights and freedoms were restricted, and compulsory acceptance of people has increased. These teachers stated that interstate and international relations were also affected, causing cooperation in some areas and tensions in some areas. On the other hand, some science teachers emphasized that they have severe results on science and health, that science may be helpless even in this century, that states should make more severe investments in health and science, and that the inconsistent statements of scientists cause distrust in people.

Solution Suggestions

As can be seen in Figure 5, the concepts that teachers express as evidence are also related to teachers' belief in the solution and rules/restrictions. Moreover, the statements in the evidence category are also related to the *changeability of information*, which is the sub-dimension of the theme of teachers' epistemological beliefs.

Figure 5

Categories Related to Solution Suggestions



Belief

Most of the teachers who participated in the research believed that a solution to Covid-19 will definitely be found. One of the main reasons behind this belief is that there have been such pandemics in history, and a solution has been found for them, or they disappeared within two years. On the other hand, some teachers stated that science and technology had developed incredibly today, so a solution will definitely be found for this pandemic. Also, some teachers emphasized that they firmly believed that the virus would mutate and that there would be a solution through herd immunity. A small number of teachers, on the other hand, stated that they believed that this virus was already an artificial virus, so the solution was ready from the beginning. On the other hand, a few teachers stated that they believed that there will be no solution to this pandemic in a short time because they believed that the virus mutates and will undergo negative changes; even vaccines cannot be a solution. This situation will last for at least five years.

Rules/Restrictions

It was determined that the teachers who participated in the research mostly expressed their views on the mask, social distance, cleaning/hygiene, herd immunity, transportation restriction, awareness-raising, and vaccination in the rules/restrictions category. By emphasizing the rules, many teachers also argued that social awareness should be gained about these rules, that the rules should be strictly supervised, and that there should be strict sanctions against those who do not comply with the rules. Some of the teachers with this view stated that if they were the administrators, they would either increase the restrictions more or apply the rules more strictly.

However, not all participating teachers agree that restrictions will be the solution. The other half of the teachers also emphasized that the restrictions were exaggerated, that curfews and closing of schools were a loss of rights, that many people violated these restrictions, and that the restrictions were not adequately supervised. Some of the social studies teachers who hold this view stated that if they were administrators, they would never close the schools, but they would remove a significant part of the restrictions, if not wholly. For example, on this subject, SST5 stated, "I do not find prohibitions such as total curfew and closing of schools reasonable. All of this is also a violation of rights."

Vaccine

Teachers suggested vaccination as another solution. Some teachers argue that the vaccine is very protective, so this pandemic can only be overcome with a vaccine. However, almost all the teachers who both recommend and do not recommend vaccination as a solution stated that they will not be subject to vaccination. They claimed that the main reason for this was that they felt insecure about this subject, there would be many side effects, the process was not transparent, they thought of their children, foreign vaccines would not be trusted, or that it was a political scenario, and that the leaders of the order could find the subjects.

Some teachers agreed to become subjects. ST3 said, "Of course, I would like to be a subject. I have no other purpose. My only purpose is to contribute to humanity", and ST4 said, "I would be at the volunteer level. Because I am a bit of self-sacrifice, I make sacrifices for my students and humanity." These statements mostly show that the reasons for teachers to be a volunteer are in line with social benefit/interest.

Herd Immunity

Except for a few teachers, all of the other teachers opposed the idea of herd immunity. A few teachers who defended herd immunity stated that there is no other solution to such pandemics. Many people will catch this virus anyway, the virus has lost its former power, and the virus must spread in a controlled way, and herd immunity should be gained. Regarding this, while STT2 expressed his belief in herd immunity as "I believe in herd immunity," ST2 stated that "Maybe it can undergo mutations and decrease by what they call herd immunity, maybe it is the only alternative," and has the opinion that mutations will reduce the effect of the virus.

All the other teachers were against the idea of herd immunity. They stated that this is ignorant courage and unscientific. European countries that try to do this do not care about their people; Turkey even brings its patients from abroad, so the idea of herd immunity cannot be applied in our country. For example, STT1 on this subject says, "Those who are weak in herd immunity will die. Therefore, this is not a preferred method. This is completely contrary to our values". These answers show that values, destiny, and feelings are the dominant factors in teachers' opposition to herd immunity.

Evidence

Teachers' statements as evidence are also related to their belief in the solution and the categories of rules/restrictions. Teachers suggested masks, social distance, and cleaning, which are expressed in the category of rules/restrictions as an example of solutions that scientists recommend, and they stated that the virus enters the body through the nose and mouth; the virus cannot enter the body when wearing a mask, disinfectants will not affect the virus, and that soap kills the virus. They also made claims that the virus would die due to increasing weather temperature. In this context, it was determined that both science and social studies teachers put forward some non-scientific personal opinions as evidence. They stated that scientists constantly say these things through the media; they trust scientists, and they hear about them from close health professionals or read about them in some sources. For example, STT1 made a statement in the form of "But some people say that it decreases in temperature." STT2 made a statement that "There may be bacteria in the environments we touch, it is said that soap kills the virus. I think it kills." Teachers who disagreed with this view stated that wearing a mask will not be a solution, the virus will be transmitted through the eyes, and the virus can stick to the body more when using the cologne. They showed the environment as a source of information on this subject. For example, STT1 stated the following on this subject "Actually, it is said that the cologne does not kill the virus; on the contrary, it sticks it more."

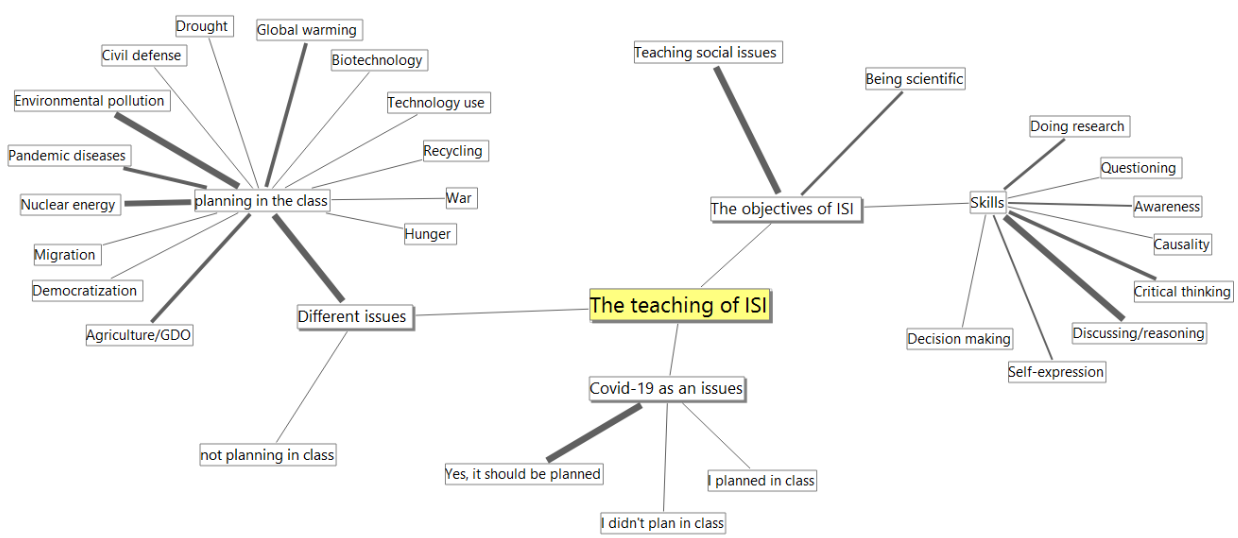
Teachers, who suggested herd immunity as a solution, claimed that the virus had to mutate and its effect would decrease. As evidence, they claimed that for the virus to survive, the human metabolism must also survive, so the virus would have to mutate, in which case the destructive power of the virus would disappear.

The Teaching of Socio-Scientific Issues

As can be seen in figure 6, the answers given by the teachers regarding the teaching of socio-scientific issues are grouped into three categories. These are the objectives of socio-scientific topics, opinions on Covid-19 as an SSI, and different topics included in the courses.

Figure 6

Categories That are Formed Related to the Teaching of Socio-Scientific Issues



Purpose

The answers given by the teachers as the primary purpose of teaching SSI are grouped as teaching social issues (23), being scientific (9), and skill acquisition (37). In particular, teachers emphasized that the use of such topics is to gain skills in students. In this process, the skills of discussing/reasoning, critical thinking, and doing research were expressed the most. In addition, the skills of decision making, self-expression, causality, awareness, and questioning are also mentioned. In addition to these, social studies teachers stated that on SSI such as Covid-19, the social dimension of such problems is more important to them, so they give more importance to this aspect; when they get into the scientific part, the discussions are blocked, and the students cannot express any opinions on this subject. On the other hand, science teachers stated that they briefly mentioned the scientific aspect of such matters and then mentioned the social dimension. Like the statement of social studies teachers, science teachers also pointed out that there were no deep scientific discussions, students got stuck, and the main arguments were in social dimensions.

Science teachers, who include SSI such as Covid-19, stated that it is to gain essential skills such as critical thinking, questioning, reasoning, using evidence, and information literacy. On the other hand, social studies teachers stated that their primary purpose is to create a discussion environment in the classroom, see different perspectives, be sensitive to social subjects, be liable to the environment and nature, and fulfill individual responsibilities.

Other Issues

The majority of the teachers participating in the research stated that they included SSI in their lessons. Environmental pollution (11), nuclear energy (10), agriculture (5), global warming (6), and pandemic diseases (6) are the leading SSI that they stated to be included in the curriculum, especially in this process. In addition, teachers stated that they considered drought (3), recycling (3), technology use (3), migration (2), war (2), hunger (2), biotechnology (2), civil defense (1) and democratization (1). as SSI.

Some of the teachers who participated in the research stated that they did not include SSI in their lessons. In this process, teachers stated that they did not specifically mention SSI such as Covid-19 because the psychology of children would be adversely affected; children had already heard about this subject everywhere. They never mentioned the Covid-19 pandemic in their classes, not to apply any pressure. Again, some teachers stated that they did not receive a letter from the Ministry of National Education that this subject should be included in the lessons. They did not include it because the students could engage in political discourse. A few teachers stated that SSI are not included in the curriculum. For example, STT1 has expressed his opinion, "Because there is a curriculum that the Ministry of National Education wants from us, and we need to be on schedule," and ST3 has expressed his opinion as "socio-scientific issues in the curriculum did not attract my attention at all."

They stated that in the subcategory of the environment, the most common topics are global warming, climate change, forest fires, biodiversity, environmental awareness, acid rain, recycling, and waste. The environment is the socio-scientific subject most frequently expressed by both social studies teachers and science teachers. On the other hand, some teachers stated that nuclear energies, health-related pandemics, conscious agriculture, and GMO products are included in the curriculum. Some social studies teachers stated that socio-scientific issues are not included in the curriculum.

A large part of the teachers stated that for effective planning of SSI in teaching to be carried out, these subjects must be included in educational programs and textbooks. Teachers stated that such subjects should be taught by creating an environment of debate and discussion, using out-of-school learning environments, different methods, and techniques. On the other hand, some teachers emphasized that there should be fun ready-made activities suitable for the level of the students in these subjects and that the lesson hours should be increased to be able to implement them. In this case, the teachers would be able to plan more efficiently.

Inclusion of Covid-19 as a Socio-Scientific Subject

Nearly half of the science and social studies teachers participating in the study stated that they include Covid-19 subjects in their classes. Teachers who stated that they included Covid-19 said that they mostly talked about what they should pay attention to at the beginning of the lesson and the importance of following the rules, but they did not plan a class and create a designed discussion environment. This process is planned mainly for informational and protection purposes.

All of the teachers stated that SSI such as Covid-19 should be included in their lessons. Social studies teachers emphasized that these subjects are social, affect everyone, take their subjects from society in their social studies, and be included for students to have a particular awareness. On the other hand, science teachers stated that science is included in these subjects and that these subjects should be given a place so that students can have different views. STT1 said, “It is highly probable that such outbreaks will occur in the future. Therefore, it should be included in both educational programs and textbooks.”

Result and Discussion

This study analyzed the epistemological beliefs and informal reasoning of science and social studies teachers regarding the Covid-19 pandemic as a controversial socio-scientific subject, using Schommer's (1990) Multidimensional Epistemological Belief System and the concepts of "structure of knowledge," "source of knowledge," and "stability of knowledge". Additionally, the personal epistemology paradigm encompasses the concepts of "speed of learning" and "ability to learn". According to Schommer's (1990) research, individuals can develop two types of beliefs in each domain. These individuals possess both naive and immature beliefs, as well as sophisticated ones. In this study, data was collected and interpreted under the structure of knowledge, source of knowledge, and stability of knowledge of Schommer's (1990) belief system. This is because the model's suggested dimensions of learning ability and speed necessitated long-term observations and interviews. Schommer (1998) stated that in the speed of learning dimension, naive people develop the belief that learning will either happen quickly or not at all, while sophisticated people believe that learning is a gradual process. Beliefs about the speed of information especially affect the time individuals spend in solving a problem. This period may vary from individual to individual depending on the individual's problem-solving ability. Given this situation, it is necessary to diversify the data obtained through observations, written documents, and interviews in order to determine teachers' beliefs about their ability to learn and the speed at which they learn. This requires a significant amount of time and interaction during the data collection process. Furthermore, identifying beliefs within the continuity of knowledge dimension becomes challenging for a variety of reasons, including the challenge of monitoring teachers throughout the study, the presence of numerous external variables, and the uncertainty of problem-solving timelines.

Results of RQ1

RQ1.1. Structure of Knowledge: Covid-19 definition

Teachers formed their epistemological beliefs about Covid-19 to further define and explain the source of this information. While some teachers defined Covid-19 as a virus-related pandemic, others described it as a conspiracy theory, an interstate show of power, or a disaster, without using the concepts of pandemic or virus. While the most common sources of information for teachers about Covid-19 are the internet, the environment, and intuition, the least used source of information is scientific publications. Teachers who believed in the natural emergence of Covid-19 emphasized that the virus originated in China and spread from animals to humans. Teachers who hold this belief believe that the primary cause of human transmission is China's unhealthy diet, a disregard for cleanliness and hygiene, a failure to take necessary precautions, and a failure to disseminate information to the world. Teachers who believed that Covid-19 was created artificially, on the other hand, claim that this virus was produced in a laboratory environment for various reasons. Almost all the teachers who expressed their opinions about the emergence of Covid-19 did not reveal any scientific evidence for the reasons they put forward. Teachers who believed that Covid-19 emerged naturally cited sources of information (internet, news, etc.) as evidence. Teachers primarily use intuitive and reasoning-based answers to explain Covid-19. When thinking and making decisions about SSI, Sadler and Zeidler (2005) argued that informal reasoning replaces formal consideration, dividing informal logic into three categories: logical, emotional, and intuitive. All participants in this study used at least one of these three classifications in the context of Covid-19.

In addition, it was determined that some misconceptions occurred in teachers' definitions. Some of those are as follows: disinfectants do not kill the virus; on the contrary, they stick to the body more, the effect of the virus decreases in temperature, soap kills the virus, and the virus cannot enter the body when wearing a mask. It was determined that teachers structured these misconceptions depending on the discourse of someone. In particular, teachers can convey their misconceptions directly to the students during the lessons, as well as cause misconceptions in many different ways, such as not having a good command of the subject and not choosing the right method and technique (Erdem et al., 2001).

RQ1.2. Source of knowledge

While most of the participating teachers believe that the pandemic started naturally due to some habits in China, some social studies teachers believed that Covid-19 was created artificially and that this virus was produced in a laboratory environment. Almost all the teachers who expressed their opinions about the emergence of Covid-19 did not reveal any scientific evidence for the reasons they put forward. Teachers also showed the tools they used as a source of information as evidence. The internet (TV, newspaper, social media channels, etc.), environment (life), and intuitive and scientific publications were primary sources of information. Among the Internet resources, several teachers emphasized academic articles. On the other hand, some teachers tried to explain Covid-19 by reasoning with intuitive expressions. In this process, they stated that they "believed that their explanation was like this," and they did not have a source for this information and had not read a scientific publication. Previous studies stated that pre-service teachers benefited from different sources of information such as school, environment, TV, and internet on a SSI (Atasoy, 2018). It has been determined that the most important source of information about nuclear power plants is the media, not scientific sources (Eş et al., 2016).

According to Schommer-Aikins (2004), individuals can develop two types of beliefs in sources of knowledge, which range from omniscient authority to reason and empirical evidence. While some individuals develop beliefs that knowledge consists of simple and separate parts (naive/immature), that experts are the source of knowledge, and that authorities disseminate knowledge, others develop beliefs that knowledge has a complex and holistic structure (sophisticated). Sophisticated individuals hold the belief that knowledge originates not only from omniscient authorities, but also from meticulous observation and reasoning. This study determined that teachers generally organized information about Covid-19 at a simpler level, developed beliefs based on the knowledge they received from an authority, and were unable to produce scientific evidence to support their beliefs. This situation demonstrates that teachers tend to hold more naive or immature beliefs.

One of the key findings of the research is that the teachers who presented various reasons for the emergence of the virus failed to provide sufficient evidence to back their claims, struggled to produce scientifically oriented arguments to support their views, or did not use any ideas at all. They even believe that these sources do not provide accurate information and should be viewed with suspicion. This situation was associated with the continuity of the information category. Studies in the literature have revealed that teachers experience various difficulties in producing and evaluating arguments in previous studies (Sampson & Blanchard, 2012). For example, Liu and Roehrig (2019) found as a result of their research examining the argumentation competencies of science teachers that although science teachers cited their arguments on climate subjects as evidence, the evidence was often insufficient to justify their claims. Similarly, studies conducted with pre-service teachers (Atasoy, 2018) or students (Wu & Tsai, 2007) revealed that participants struggled to produce arguments based on scientific evidence.

RQ1.3. Stability of knowledge

Another result reached in the research is that the participating teachers believed the statements of official institutions such as the World Health Organization, the ministry of health, the scientific council, or independent scientists as "accurate information". Some teachers, on the other hand, expressed that they have to believe the statements of these institutions. While the majority of the teachers found scientists reliable because they think they have no interests even though they have different rhetoric, they do not find the statements of policymakers reliable for various reasons. On the other hand, some teachers think that the information they have obtained was not certain, arguing that there are contradictions in the information received and they are suspicious of it. In particular, they stated that they did additional research to confirm the continuity of the information they obtained from the internet. In Baxter Magolda's (1993) Epistemological Projection Model, the development process of individuals' epistemological beliefs is grouped under four categories. These are: absolute category, transitional category, independent category, and contextual category. In the absolute category, individuals believe that the information is certain and transmitted by an authority. In the transitional category, the belief that the information will not be sure and the authority cannot know everything is dominant. In the context of active learning and critical thinking in the independent category, individuals believe that authority is not the only source of knowledge and that the individual's thought is also valuable. In the contextual category, the individual discusses different perspectives and creates his viewpoint in this context. The results obtained in the research showed that most of the teachers, in particular, are in the absolute category class. In addition, it can be said that several of the teachers are in the transitional and independent categories. One dimension of epistemological belief is the source of knowledge. Especially as this process is emphasized in the Epistemological Reflection Model, it can be defined as an individual with naive epistemological understanding, (absolute and transitional category) defending authority, or that knowledge is transmitted by omniscient authorities and individuals with a sophisticated epistemological understanding (independent and contextual category) (Hofer & Pintrich, 1997; Schommer, 1990). In this respect, it can be said that the teachers participating in the study have a naive epistemological understanding of the absolute and transitional category, where they develop beliefs based on the information conveyed by the authorities about Covid-19.

Results of the Covid-19 Pandemic and Belief in Solution

The most emphasized categories in teachers' opinions about the results of the Covid-19 pandemic are social/psychological, economic, and educational results. These were followed by international, environmental, health, scientific, and political results. In addition, while teachers in particular think that Covid-19 has positive effects as environmental and scientific results, they believed that negative impacts occur in social/psychological, political, education, health, and economic categories. Socially/psychologically, the teachers stated that they would never return to their old behaviors. They feared losing their relatives to the pandemic and worried about the future. They feared loneliness and had an obsession with cleanliness, insecurity, and uneasiness. While emphasizing the adverse results of the pandemic on the national and global economy, they stated that children were affected psychologically in terms of education, and many new problems arose with the online education process. In other dimensions, they emphasized that the power of governments increased in the world, human rights and freedoms were restricted, it had severe results on science and health, science can be helpless even in this century so states should make more serious investments in the field of health and science, and inconsistent statements of scientists cause distrust in people. The effects on the environment are positive. These are emphasized as the relaxation of the environment and the minimization of the damage caused by human beings to the environment during this process.

All the participating teachers believed that a solution will definitely be found for Covid-19 because they trust science and scientists. A significant part of the participants believed that the most critical solution, for now, is to comply with the precautions (mask-distance-cleaning) recommended by scientists and to be vaccinated. Half of the participants believed that there should be restrictions, that these restrictions would increase even more if they were the administrator, and that everyone has to follow the rules. Herd immunity was not seen as a solution by the majority of participants. The fact that the answers given by teachers about herd immunity were emotion-based, away from a logical context, shows that they have problems in the process of creating arguments. In addition, the arguments developed do not contain statements aimed at determining the correctness of the arguments with supporting or opposing evidence. In this context, the arguments developed by teachers about herd immunity can be grouped as poorly structured, incomplete, unclear, and not based on rules (van Bruggen et al., 2003). This result shows that teachers' argumentation skills should be improved. According to Britt and Larson (2003), the ability to construct and understand arguments is a primary indicator of literacy. In addition, Jonassen and Kim (2010) concluded in their study that teachers' pedagogical competencies are essential in the argumentation process of students. It has been emphasized that if teachers are weak in creating arguments and cannot create appropriate learning environments, it also makes their students unable to produce quality and strong arguments.

Results of RQ2. Teaching socio-scientific issues

Teachers point out that SSI such as Covid-19 should be included in the curriculum due to some gains. Environment, nuclear energy, health, agriculture, and GMO products are the leading SSI that participant teachers stated exist in the science and social studies curriculum in Turkey, apart from the Covid-19 pandemic. The environment subject is the socio-scientific subject most frequently expressed by both social studies and science teachers. Some teachers stated that SSI are not included in the curriculum. In the last 30 years, there have been serious changes in science education in Turkey. Since 2013, SSI have been directly included in the science curriculum (MoE, 2013). Finally, the program update made in 2018 aimed to develop students' reasoning skills, scientific thinking habits, and decision-making skills by using socioscientific subjects (MoE, 2018). The social studies curriculum has undergone radical changes since 2005. The latest update in 2018 aimed to provide the student with the knowledge, skills, attitudes, values, and behaviors necessary for life in a structure that concerns all humanity. Ultimately, the acquisitions related to socioscientific subjects are clearly and directly included in the curriculum of science and social studies courses in Turkey (Türksever et al., 2020).

Teachers grouped the main purpose of SSI as teaching social subjects, being scientific, and gaining skills. In particular, teachers emphasized that the purpose of such topics is to develop skills in students. The most expressed skills in this process were discussing/reasoning, critical thinking, and conducting research. Additionally, the research highlighted the skills of decision-making, self-expression, causality, awareness, and questioning. Therefore, the results of this research show that teachers have a positive attitude toward the teaching of SSI. Numerous studies have determined that SSI enhances students' critical thinking and scientific literacy (Zeidler & Nichols, 2009), fosters empathy and respect, develops reasoning skills (Atasoy et al., 2019), and enhances questioning skills (Evren & Kaptan, 2014) by enhancing moral sensitivity (Fowler et al., 2009).

Educational Implications

The primary purpose of social studies is to acquire citizenship awareness, knowledge, skills, attitudes, values, and behaviors necessary for social life. It aims to develop the thinking and decision-making skills needed for the individual to solve social problems. Social-scientific subjects could feature citizenship, scientific literature, and sustainable development under the three headings. Ultimately, one of the essential goals of science education is character development, including moral decision-making and the development of democratic citizenship (Driver et al., 2000; Sadler & Zeidler, 2005; Solomon, 1994). Examining the literature reveals that SSI significantly contributes directly to citizenship competencies. Özden (2015) found that activities based on SSI can improve the citizenship competencies of students in his study. Lee et al. (2013) discovered that SSI enhances global citizenship values. Ratcliffe and Grace (2003) state that SSI increases ethical and moral sensitivity and encourages individuals to be good citizens.

Therefore, SSI directly serves the purposes of both the science and social studies courses. However, the results of this research also reveal that science and social studies teachers lack the necessary skills to effectively teach these subjects. Some of the study's teachers noted concerns about using these and similar SSI in their lessons. Teachers who do not have the necessary resources are unable to teach SSI in a planned manner Teachers believe that curriculum and textbooks should include SSI to effectively plan, and they believe that teaching such subjects should involve creating an environment of debate and discussion, utilizing out-of-school learning environments, and employing different methods and techniques. However, teachers do not consider themselves to have this qualification. In previous studies, both science teachers (Gardner & Jones, 2011; Lee et al., 2006; Lee & Witz, 2009; Namdar & Tuskan, 2018; Sadler et al., 2006) and social studies teachers (Busey & Mooney, 2014; Chikoko et al., 2011; Kuş, 2015; Kuş & Öztürk, 2019) face various difficulties in terms of pedagogical and content knowledge.

Yang and Anderson (2003) distinguished between two types of research: scientifically oriented research and socially oriented research, while examining solutions to a nuclear energy problem. This study found that both social studies and science teachers conducted more social-oriented studies related to the Covid-19 pandemic. The teachers attributed this situation to the students' inability to continue and deepen their discussions in the scientific dimension. It seems quite normal for social studies teachers to focus on the social aspect of SSI since the courses they take during their undergraduate education are generally social, and social-based subjects are predominant in the curriculum. However, the inability of science teachers to conduct a scientifically based discussion may lead them to primarily focus on the social aspect of SSI.

This study's data is based on in-depth interviews with teachers. Future studies can incorporate observations, both inside and outside the classroom, and teacher documents such as materials and lesson plans into the data analysis process through triangulation. This approach can enhance the internal reliability of the collected data.

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Preparing Teachers for Content-specific Consultations: Perspectives From Four Continents

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ABSTRACT

This paper describes an international collaboration of teacher educators from four countries that developed a method of preparing preservice mathematics and special education teachers to consult to address the mathematics learning needs of K-12 students with special education needs within inclusive classrooms. Researchers from Germany and the United States present case summaries of findings from implementations in their respective countries, and researchers from Brazil, China, Germany, and the United States add their context-specific analysis of the implementations. The researchers identified ways in which they can provide opportunities for general education and special education preservice teachers to learn to synthesize their knowledge to change classroom instruction to support the learning of students with special education needs. The paper concludes by using a communities of practice lens to discuss implications for preparing preservice teachers for mathematics-specific consultations in multinational contexts.

Keywords: Special Education, Consultation, Teacher Learning

Introduction

In 1994, representatives from 92 governments and 25 international organizations signed the Salamanca Statement (UNESCO, 1994) committing themselves to *inclusive* education for all students, regardless of special education status. This document defined *inclusive* education as allowing students with special education needs to attend their regular, local schools. Rather than establishing special education schools, the Salamanca statement admonished countries to build capacity within general education schools to meet the needs of all diverse learners. Therefore, there has been an ethical obligation for the signatory countries to develop and adopt policies that result in effective instruction being delivered to *all* students. Indeed, as part of the capacity-building process, the statement specifically articulated the need for signatory countries to ensure that teacher preparation programs would adequately prepare future teachers to provide effective instruction to students with special education needs within inclusive, general education settings. The policy shift toward inclusion has profound implications for the need to update and revise the preparation of general education and special education teachers.

Despite the fact that international policy documents have continued to emphasize the importance of attending to teacher preparation for inclusion (UNESCO, 2000, 2009), an international survey of teachers reported that teachers across 18 countries identified *teaching special needs students* as their most pressing need for professional development (Schleicher, 2012). As the European Agency for Development in Special Needs Education (2011) explicated, "one of the key priorities for teacher education . . . [is] to review the structure to improve teacher education for inclusion and to merge the education of mainstream and special education teachers" (p. 18). Although the field of teacher preparation has recognized the need to provide integrated opportunities for special educators and general educators to collaborate, research in this area has been slow to emerge. There is currently no consensus as to the ways in which this integration can be accomplished (e.g., Blanton et al., 2014).

In an effort to address this lack of research on preparing teachers for inclusion, the authors of this paper (education researchers from four countries) have formed an international collaboration, which we have conceptualized as a multi-national community of practice (Wenger et al., 2002). Situated in Brazil, China, Germany, and the United States, our research teams hold the common goal of improving the preparation of teachers in our respective countries to meet the needs of students in inclusive settings. Rather than work in parallel and in isolation, we have chosen to cultivate a *shared but given goa*l (Clausen et al., 2009; Quebec Fuentes & Spice, 2017; Quebec Fuentes & Bloom, 2021) for researching one potential way to prepare general education and special education teachers to collaborate to meet the needs of *all* students in the mathematics classroom: specifically, we focus on how to equip special and general education teachers to engage in mathematics-specific consultations and integrate their respective knowledge bases to meet the mathematics learning needs of students with special education needs.

As we have described previously (van Ingen et al., 2016), there are multiple ways (beyond consultation) that general education and special education teachers can collaborate to provide effective instruction for students with special education needs. One type of collaboration is co-teaching, in which both the special education teacher and the general education teacher collaborate together inside the classroom. Although co-teaching can be a powerful form of collaboration, it is not always feasible due to the fact that there have simply not been enough special education teachers to be present in each classroom with students with special education needs (e.g., McLeskey et al., 2004). Additionally, the inclusion of both a special education teacher and a general education content teacher in a classroom does not necessarily guarantee that the nuanced learning needs of a student with special education needs will be met (Moin et al., 2009). Another potentially effective form of collaboration is the consultation (Busse et al, 1995; Medway & Updyke, 1985; Sheridan et al., 1996). Discussion on consultations in education can be found since the 1980's and began with a focus on consultations around behavioral issues (e.g., McDougal et al., 2005; Noell et al., 2005; Sheridan et al., 2001; Wilkinson, 2005). Much of the cumulative body of research on consultations in education centers around addressing the needs of students with special education needs, especially students with more involved disabilities (e.g., autism, intellectual disorders, multiple disabilities). For example, Ruble et al. (2010) reported on the findings of a study examining the outcome of the Collaborative Model for Promoting Competence and Success (COMPASS) between parents and teachers to improve individual education plan outcomes for children with autism.

The Mathematics-Specific Consultation

Leveraging Diverse Expertise to Create M-SEPACK

Successful consultations occur in the contexts of professional relationships in which the collaborators each have their own areas of expertise (Alpert & Meyers, 1983) and in which there is reciprocity in exchanging knowledge (Sundqvist & Strom, 2015). For teachers, this expertise certainly includes knowledge of the content areas being taught (in this case mathematics and special education), but it also includes the specialized knowledge of *how* to teach content- knowledge that has been named pedagogical content knowledge (PCK, Shulman, 1986; van Driel et al., 1998). PCK is a type of expert knowledge unique to teachers, and it allows them to integrate knowledge of the content area, the use of effective instructional practices specific to that content area, knowledge of the student, and knowledge of the learning environment to improve content-specific learning outcomes for students (Cochran et al., 1993).

With regard to the content area of mathematics, Ball et al. (2008) identified three different types of PCK: knowledge of content and students (KCS), knowledge of content and teaching (KCT), and knowledge of content and curriculum (KCC). Our research team has identified analogous knowledge types in the realm of special education (van Ingen Lauer et al., under review). In the mathematics-specific consultation, the mathematics teacher brings extensive mathematical knowledge for teaching (MKT, Ball et al., 2008), among other forms of knowledge, to the consultation, and the special education teacher provides extensive special education knowledge for teaching (SEKT), among other forms of knowledge, to the consultation. Together, they synthesize a blending of these knowledge bases to form mathematics-special education pedagogical content knowledge (M-SEPACK). This is, by definition, the type of knowledge that is needed to meet the mathematics learning needs of a student with special education needs. Table 1 provides a visual representation of how MKT and SEKT are combined to form the three types of M-SEPACK: (a) Knowledge of Content and Teaching in Special Education, (b) Knowledge of Content and Students in Special Education, and (c) Knowledge of Content and Curriculum in Special Education (see van Ingen Lauer et al., under review, for an extensive discussion of each category and subcategory of knowledge type).

Table 1

Framework for Mathematics-Special Education Pedagogical Content Knowledge (M-SEPACK)

Mathematical Knowledge for Teaching (MKT)	+	Special Education Knowledge for Teaching (SEKT)	=	Math-Special Ed Pedagogical Content Knowledge (M-SEPACK)
Knowledge of Content and Teaching (KCT)	+	Knowledge of Teaching and Special Ed (KTSE)	=	Knowledge of Content and Teaching in Special Ed (KCT-SE)

Mathematical Knowledge for Teaching (MKT)	+	Special Education Knowledge for Teaching (SEKT)	=	Math-Special Ed Pedagogical Content Knowledge (M-SEPACK)
Knowledge of Content and Students (KCS)	+	Knowledge of Students and Special Ed (KSSE)	=	Knowledge of Content and Students in Special Ed (KCS-SE)
Knowledge of Content and Curriculum (KCC)	+	Knowledge of Curriculum and Special Ed (KCSE)	=	Knowledge of Content and Curriculum in Special Ed (KCC-SE)

In summary, the mathematics-specific consultation is designed to capitalize on the integration of the PCK in mathematics and the PCK in special education to address the particular mathematics learning needs of students with special education needs. Utilizing the consultation process, the mathematics and the special education teacher can leverage their collective knowledge of the mathematics content, effective mathematics instructional practices generally, the learning environment, and the needs of students with special education needs, including effective instructional practices for students with special education needs, to improve these students' mathematics outcomes.

The Consultation Process

Table 2 shows the step-by-step mathematics-specific consultation.

Table 2

The Mathematics-Specific Consultation Template Used in the German and American Studies

STEP 1: Completed by the Mathematics Teacher- Identify the Student	
Student Pseudonym:	
Grade Level:	
Identify Student Learning Needs- Include information on diagnosed learning exceptionality and/or below level performance. Include description of student participation in math class.	
Target Content Standard:	
Target Mathematical Practice/Process:	
Cognitive (Diagnostic) Interview Questions:	
STEP 2: Completed by the Mathematics Teacher- Post Diagnostic Interview	
OBSERVATIONS	2.1 What did you learn about the student's UNDERSTANDING of the content standard that you targeted? Provide a pictorial depiction of student work and/or paraphrase at least one key moment during the interview.
	2.2 What did you learn about the student's ENGAGEMENT in the mathematical practice that you were targeting? Describe HOW the student engaged in the mathematics activities and the extent to which that did or did not reflect the targeted mathematical practice:
	2.3 Record any other observations about your interaction with this student that may help the SPED consultant better understand the student's needs:

<table>
<tr><td rowspan="3">Q
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N
S</td><td>2.4 Record at least one question that you have for your SPED consultant regarding understanding your STUDENT and how his or her disability/low achievement affects learning:</td></tr>
<tr><td>2.5 Record at least one question that you have for your SPED consultant regarding TEACHING actions that you could take to support student learning in regard to the CONTENT standard:</td></tr>
<tr><td>2.6 Record at least one question that you have for your SPED consultant regarding TEACHING actions that you could take to support student engagement in the targeted mathematical practice:</td></tr>
<tr><td colspan="2" align="center">Meeting #1 for Mathematics Teacher and Special Education Teacher</td></tr>
<tr><td colspan="2">STEP 3: Completed by the Special Education Teacher</td></tr>
<tr><td colspan="2">Summarize what you learned about the 3 C’s: Child, Content, Context.</td></tr>
<tr><td colspan="2">Create some instructional hypotheses about what the student is able to do and not do in the math class given the information that was presented.</td></tr>
<tr><td rowspan="4">A
N
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W
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R
S</td><td>Please answer the Mathematics Teacher’s questions. Include:</td></tr>
<tr><td>Explain how the exceptionality affects the student’s learning of mathematics.</td></tr>
<tr><td>Put research-supported suggestion(s) into the context of the math classroom. Provide examples of how your suggestions might play out with the content and in the context of the classroom that has been presented. Provide the reference for the research.</td></tr>
<tr><td>Attend to and provide recommendations for supporting student engagement in the mathematical practices. Make suggestions contextualized and specific.</td></tr>
<tr><td colspan="2" align="center">Meeting #2 for Mathematics Teacher and Special Education Teacher</td></tr>
<tr><td colspan="2">STEP 4: Completed by the Mathematics Teacher After Second Meeting</td></tr>
<tr><td colspan="2">This is what I learned from my consultant:</td></tr>
<tr><td colspan="2">This is the plan for working with the student (Be specific about implementation AND explicit about how the research informs this implementation.)</td></tr>
<tr><td colspan="2" align="center">The Mathematics Teacher Implements the Plan</td></tr>
<tr><td colspan="2">STEP 5: Completed by the Mathematics Teacher After Implementation</td></tr>
<tr><td colspan="2">Collect data from work with the student. Provide evidence for what worked or did not work.</td></tr>
<tr><td colspan="2" align="center">Meeting #3 for Mathematics Teacher and Special Education Teacher</td></tr>
<tr><td colspan="2">STEP 6: Completed Both Teachers After Meeting #3</td></tr>
<tr><td colspan="2">Reflections on the Consultation Process: What worked well in the consultation? What would you want to do differently next time you engage in a consultation?</td></tr>
</table>

In STEP 1, the mathematics teacher summarizes the math-related learning needs of the student including areas of difficulty and observations made in class pertinent to learning math and their identified disability. The math teacher also shares both the *what* of mathematics learning (content standards such as adding fractions or solving two-step algebraic equations) and the *how* of mathematics learning (the mathematical practices—the processes or habits of mind such as making sense of problems or making use of structure). Having identified the target student and target mathematical content, the mathematics teacher prepares questions/prompts for the ensuing cognitive/diagnostic interview centered around the target math content and practices.

In STEP 2 of the mathematics-specific consultation the teacher conducts a cognitive interview with the student. The focus is to learn what the student does and doesn’t understand about the target mathematics and what the teacher learned about how the student engaged in the target mathematical practice(s). We have found it helpful if the math teacher shares at least one key moment or incident during the interview that stood out to them as well as any information that will help the special education teacher consultant to understand the student's needs. Then, the math teacher develops one question they have for the special education teacher about the *student and how their disability/low achievement affects learning,* one question they have for the special education teacher about *teaching actions they could take to support the student in learning the target mathematics content*, and one question they have for the special education teacher about *teaching actions they could take to support the student to successfully engage in the target mathematics practice(s)*. The mathematics teacher uses these questions/prompts to elicit the special educator's expertise about the special education needs of the student, and potential teaching strategies that might be effective given their needs. After STEP 2 the mathematics teacher and special education teacher meet to discuss what the mathematics teacher learned.

In STEP 3, the special education teacher reflects on the information shared by the mathematics teacher and their ensuing discussion during their first meeting together. The special education teacher then considers how this information informs the 3 – Cs, the **C**hild, the **C**ontent, and the **C**ontext. When doing this, the special education teacher writes key insights (two to three sentences each) related to the child/student in terms of learning (how particular characteristics of their learning exceptionality could be impacting their learning – e.g., working memory difficulties), how this might affect learning the target mathematics content and mathematical practice in particular (e.g., perhaps the student would benefit from use of the concrete-to-representational-to-abstract instructional sequence), and what might be possible facilitators and barriers based on the context/environment (e.g., how noise and movement could be distracting for the student). Based on the 3 Cs the special education teacher creates an instructional hypothesis that identifies: 1) the mathematics to be learned, 2) what the student can do given the target mathematics, 3) what the student cannot do given the target mathematics, and 4) why they are having difficulty sharing with the mathematics teacher. This instructional hypothesis becomes the focus of instructional decision-making. Additionally, the special education teacher writes brief answers to each of the three questions posited, and shared by the mathematics teacher in STEP 2, including support from research. At this point, the mathematics and special education teachers meet to discuss the special education teacher's thoughts including possible teaching actions that could be taken regarding the instructional hypothesis.

In STEP 4 and STEP 5 the mathematics teacher writes what they learned from their special education consultant, develops a plan (being explicit about teacher actions and how research supports the plan), and implements the plan). After implementing the plan, the mathematics teacher and the special education teacher meet to discuss how the plan is going and to make any adaptations as needed. In STEP 6, the two teachers meet to reflect on their consultation including what worked well and what they would do differently the next time. This is also time for the two teachers to continue cultivating a positive relationship for future consultations.

Together, the two educators use the specialized knowledge of teaching mathematics (brought to the consultation by the mathematics teacher) and the specialized knowledge of teaching students with special education needs (provided by the special education teacher) to develop a very specific plan to teach the specified mathematical content to the target student. Table 2 defines the step-by-step process we used as a framework in our multi-national collaboration to prepare preservice teachers to engage in mathematics-specific consultation.

Shared Goals and Research Questions

The aims of this article are to (a) briefly describe current teacher preparation policies and practices in each of our countries related to inclusion, (b) present case summaries on data from two implementation studies: Implementation 1 (Germany) and Implementation 2 (United States), and (c) initiate an international discussion about the findings and implications given our four different contexts. Although we report case summaries from only two of the four research teams, we provide details on the backgrounds and perspectives of researchers from all four countries to accurately reflect our multinational collaboration and to contextualize the ensuing conversations between the four respective research teams.

Our international collaboration began with a shared understanding of the mathematics-specific consultation as a cycle that had been described in van Ingen et al. (2016) and operationally defined in Table 2. We then started developing context-specific interventions to prepare preservice teachers to engage in these consultations. Our shared goal was to prepare our future teachers to leverage consultation to create the M-SEPACK that would be needed to meet the mathematics learning needs of students in their inclusive classrooms. As we designed unique implementations specific to our respective contexts, we shared an overarching research question:

> To what extent were our preservice teachers able to synthesize M-SEPACK during the consultation process?

As a multi-national community of practice, we also extended our *shared but given goal* to a *shared beyond given goal* (Quebec Fuentes & Spice, 2017; Quebec Fuentes & Bloom, 2021) of understanding what consultation looked like in our diverse contexts and how each team made unique modifications to how they thought about preparing teachers for content-specific consultation in their unique circumstances. We were interested in the similarities and differences in how we both implemented our research as well as how we reflected upon our shared and different experiences.

Contexts for Potential Consultations Across Four Continents

Brazil

Concern about inclusive practices in Brazilian schools intensified after the Declaration of Salamanca in 1994. The publication of the National Policy on Special Education for the advancement of Inclusive Education in 2008 was momentous as it initiated a shift in national policy. The document presents and defines various methods of implementing inclusive practices for students with special education needs. One recommended inclusive practice from this document is for the student with special education needs to attend most general education classes and receive specialized educational services through a special education teacher in a resource room. Another recommended practice is the adoption of collaborative teaching. This practice has been researched in Brazil since 2004 (Capellini, 2004; Mendes et al., 2011; Zanata 2004).

As has been acknowledged internationally, in order for collaborative teaching to occur in Brazil, it is necessary that future teachers are prepared to engage effectively in collaborations between general and special education teachers. Thus, teacher educators in Brazil need to closely couple theory, research, and practice related to collaboration to support the skills and dispositions of general and special education teachers to engage in effective collaboration. Currently, Brazilians have focused on the continuous professional development of special education teachers to engage in collaboration. However, as Maturana et al. (2019) point out, this ongoing professional development has not led to significant changes in teachers' practice. Therefore, it is necessary to think innovatively about connecting preservice and inservice teacher professional development. In particular, we suggest that the internship of preservice teachers is a critical juncture for training in one form of collaboration—the consultation. The possibility of partnership between universities and K-12 schools via the internship is a unique moment to implement collaborative consultations. As an example, the Brazilian University X campus has offered courses to teachers of public schools that are integrated with undergraduate courses, enabling the possibility of preservice teachers to consult with special education professionals in the planning of didactic sequences for the teaching of students with special education needs.

China

Starting in 1978, a program of economic reform and the opening up of the economy to foreign investment have had an influence on educational policy in China. China's special education policy has been influenced by both international trends in special education development and ensuing domestic educational reform. Prior to the 1980s, very few general education schools in China supported students with special education needs. During the 1980s, the Learning in Regular Class program (LRC program), in which children with special education needs would be taught in regular education settings, was formally proposed and supported. This meant segregated special education schools were not the only placement option for children with special education needs, and some of these students were placed in regular schools or special classes in regular schools. By 2012, 52.7% of students with special education needs in the years of compulsory education had participated in the LRC program (Ministry of Education, 2012). China now has the goal to prepare prospective teachers for inclusive classes and to foster corresponding competencies. It is desirable that all prospective teachers acquire subject knowledge, general pedagogical competencies, and participate in opportunities for teaching in inclusive settings. Up to this point in time, cooperation between different teaching professions has been emphasized, but there has been no consensus on how to prepare teachers to engage in collaborations in China. (Ma & Tan, 2010). The possibility of preparing preservice general education and special education teachers to engage in consultation is a promising new direction that can help educators fulfill the LRC program and other policy requirements.

Germany

The ratification of the Convention on the Rights of Persons with Disabilities (United Nations, 2009) led Germany to intensify efforts of inclusive learning and to widen their previous considerations for an integrative school system. Concurrently, preservice teacher preparation for inclusive classes has been brought into focus. The standing Conference of the Ministers of Education and Cultural Affairs (KMK, 2015) commits Germany to prepare prospective teachers for inclusive classes and to foster corresponding competencies. This implies that all preservice teachers should develop general pedagogical competencies for dealing with diversity of learning needs and basic competencies for working with students with special education needs (KMK, 2015). Interdisciplinary cooperation between different teaching professions is emphasized as a central condition of success for inclusive learning (KMK, 2015). The preparation of preservice teachers for inclusive teaching is seen as a cross-cutting task for all related disciplines (KMK, 2015). In order to implement these requirements for teacher education, the German government initiated an extensive program, called "Qualitätsoffensive Lehrerbildung." Fourteen out of 16 of the projects funded by this program explicitly emphasize inclusion as one of their research priorities. At the German University X, the state-funded project "ProfaLe" pursues the goal of preparing preservice teachers for inclusive mathematics teaching. As a part of this effort the content-specific consultation template presented in this article was integrated into a university course for prospective teachers of primary, secondary, and special education, which accompanied a field-based internship.

United States

In 1975, the passing of the first Individuals with Disabilities in Education Act (IDEA) established the expectation in the United States that general education and special education teachers would share responsibility for educating students with special education needs. This law, updated in 2004, has set the expectation that students in the United States will be educated in the *least restrictive environment* which most often means general education classes in public schools. In fact, in 2015 (the most recent year for which data is available), about 95% of students aged 6-21 served under IDEA (students with special education needs) were enrolled in general, public education schools, and of those students, 63% spent the majority of their day (>80%) in general education classrooms (National Center for Education Statistics [NCES], 2017).

Recognizing the central importance of general education teachers being able to meet the needs of students with special education needs, the Interstate Teacher Assessment and Support Consortium (Council of Chief State School Officers [CCSSO], 2011) included in their definition of teacher effectiveness Standard 2f which stated that "the teacher accesses resources, supports, and specialized assistance and services to meet particular learning differences or needs" (p. 11). Clearly, legislative and policy documents in the United States have made a strong commitment toward inclusion and the expectation that teachers will collaborate to meet the needs of students with special education needs. Unfortunately, there is no consensus in the United States as to how to prepare teachers to engage in these collaborations (Blanton et al., 2014; McKenzie, 2009). Consultations represent a new possible avenue for teachers to leverage in order to meet the needs of students with special education needs.

Although the contextual details of the commitments to inclusion in Brazil, China, Germany, and the United States are unique, the summaries above show remarkable similarities. Each country has acknowledged that the commitment to inclusion necessitates changes to teacher preparation. However, none of the countries has yet to articulate fully the path to prepare general education and special education preservice teachers to collaborate with each other to address the needs of students with special education needs. Each context shows the potential for innovation by introducing collaboration opportunities in teacher preparation.

Preparing Preservice Teachers to Engage in Mathematics-Specific Consultations: Summaries of Two Studies

In this section, we provide summaries of two studies conducted within this international collaboration, one conducted in Germany and the other in the United States. The purpose of reporting on these two particular studies is to highlight the type of research in which we are engaging within our different teacher preparation contexts and to provide the context for an international discussion among researchers from our four countries about the findings and implications of our international research collaboration. In both studies, preservice teachers engaged in a form of consultation, and the researchers examined the extent to which this consultation process enabled the preservice teachers to generate the M-SEPACK needed to teach mathematics effectively to students with special education needs.

Study 1 Summary: Germany – A University-Based Approximation of Mathematics-Specific Consultation

This summary reports the initial findings of using the mathematics-specific consultation template (Table 2) in a course at German University X immediately prior to the preservice teachers' internship. The focus of this implementation study was to gain an initial understanding of how university-based faculty, initially implementing the mathematics-specific consultation, can prepare teachers for consultation through an approximation of the practice.

Context

We, the German research team, began our study with a commitment to prepare future teachers for interdisciplinary collaborations that integrate the perspectives of special education and mathematics education (e.g. Wang & Fitch, 2010; Wolfswinkler et al., 2014). To reach these objectives, we applied a newly designed teacher preparation concept at a German university (Bock & Siegemund, 2017; Siegemund & Bock, 2018). Undergraduate-level preservice teachers from both disciplines, mathematics education (primary education) and special needs education, who were enrolled in university-based courses were paired in interdisciplinary teams to work on case studies focused on teaching students with special education needs. In subsequent field experience practicums at local schools, the preservice teachers gained first-hand teaching experiences as part of their collaboration in interdisciplinary teams.

Methods

We introduced the consultation template (Table 2) directly before the preservice teachers started their internship. In session 12 of 14 of the university course, we explained the goals and the structure of the template to the preservice teachers. We then gave them a case study which they explored in interdisciplinary pairs (teams). The case study included information according to STEP 1 of the template and an additional transcription of a corresponding diagnostic interview. The case centered around the problems of an eight-year-old boy in his second year of school. Diagnostic procedures showed that the student performed in the bottom 2% of students in both mathematics and literacy. In mathematics class, he was often distracted by many objects and showed only short periods of on-task behavior. The preservice teachers, working in teams, then completed STEP 2 of the consultation template together. This step was focused on summarizing the information learned from the case (STEPS 2.1, 2.2, and 2.3 on Table 2) and generating targeted questions (Questions 2.4, 2.5, and 2.6 on Table 2) about the student's specific special education needs and teaching actions that might be effective at meeting those needs. Subsequently, we collected the written documents and discussed the case as a class. These documents became Data Set 1 for this study. Based on the content of these documents, the two course instructors role played the first consultation (Meeting #1 on Table 2) to act as a model for the preservice teachers. Then, in preparation for session 13 of the course, the preservice teachers filled out STEP 3 in the role of the special education consultant answering the questions generated in STEP 2 (Answers to 2.4, 2.5, and 2.6 on Table 2). This set of documents made up Data Set 2 for this study.

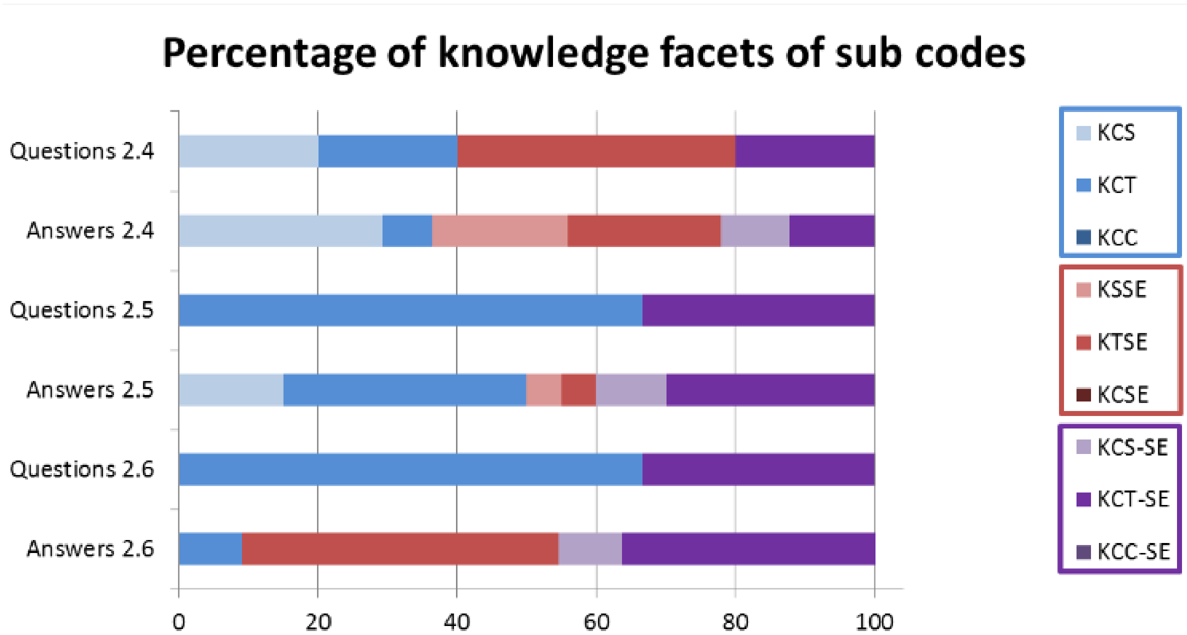
In the following course session, the preservice teachers discussed in small groups the result of their homework to prepare for the second meeting of the consultation. Then they engaged in a role play as an approximation of practice (Grossman et al., 2009) for Meeting #2 of Table 2. One course instructor took the role of the teacher and participants of the course took the role of the special education consultant. During class, the role play was enacted multiple times, with a different preservice teacher acting as consultant each time, with the other students observing. The second lecturer helped to steer the role play according to the aims of the consultation. In session 14, some additional time was given to answer questions about the consultation and how it should be applied in the internship.

Findings

We analyzed Data Set 1 (the questions generated by the preservice teachers) and Data Set 2 (the answers generated by the preservice teachers) by using the M-SEPACK framework (see Table 1) in order to understand the types of knowledge generated in the role-play consultations. Two researchers coded both data sets according to the type of M-SEPACK knowledge the preservice teachers used in generating or responding to the questions. We present the findings from a qualitative content analysis (Kuckartz, 2017) in which we analyzed the written questions of one mathematics preservice teacher that corresponded with questions 2.4, 2.5, and 2.6 in Table 2 and the answers to 2.4, 2.5, and 2.6 of one special needs education preservice teacher that corresponds to STEP 3 in Table 2. Overall, the mathematics preservice teachers formulated 11 questions corresponding to steps 2.4, 2.5, and 2.6 of the template. There were 11 corresponding answers from the special education preservice teachers. The three types of M-SEPACK knowledge that were generated in these questions and answers are presented in Figure 1.

Figure 1

The Types of M-SEPACK Knowledge That Were Generated in the German Mathematics-Specific Consultations



Regarding mathematics teachers' questions and special education teachers' answers (STEPS 2 and 3 of the protocol in Table 2) we noted that the nature of the questions by the mathematics teachers and the answers of the special education teachers were qualitatively different. Mathematics teachers were more focused on knowledge of teaching (KCT, KTSE, and KCT-SE). For example, questions developed by the mathematics teachers in STEP 2, 2.4 of the protocol intended to utilize knowledge of the special education needs of the student - Knowledge of Students in Special Education (SEKT). The mathematics preservice teachers prioritized questions focused on teaching actions, Knowledge of Content of Teaching (KCT) and Knowledge of Teaching Special Education (KTSE), rather than questions focused on understanding Knowledge of the Student Special Education. In other words, the mathematics teachers tended to not focus on the student and their exceptionality-based learning needs. In contrast, for questions raised by the mathematics teacher, the special education preservice teachers, when answering the questions (STEP 3 of the protocol), tended to provide knowledge related to the student and their special education needs (KSSE) and knowledge of teaching in special education (KTSE; KCT-SE) despite the mathematics teacher not asking for information focused on the student and the special education needs. Thus, although the mathematics preservice teachers failed to ask questions that focused on the impact the student's special education needs have on learning (as evidenced by the lack of questions coded as Knowledge of Students in Special Education), some special education preservice teachers still provided this specific information. The same trend is true for STEP 2, 2.5 questions from the mathematics teachers and the related answers by the special education teachers.

We also observed that most of the answers to the questions from 2.6 (which were designed to elicit the integrated M-SEPACK knowledge) involved only special education knowledge. The special education preservice teacher did not contextualize the answers to the specific content area of mathematics but gave general teaching recommendations. We also found that there were no statements that referred to the coordination and sequence of learning steps in a longer-term perspective of the curriculum (Code: Knowledge of Content and Curriculum, Knowledge of Content and Special Education, Knowledge of Content and Curriculum for Special Education). It seemed to be difficult for the preservice teachers to analyze and to discuss the case in a long-term perspective. Additionally, some parts of the transcript could be categorized as general pedagogical knowledge (Shulman, 1986), as a fourth main category.

Overall, this case analysis exemplifies the differing facets of knowledge of both the special education and mathematics preservice teachers. Whereas the special education preservice teacher preferentially attended to aspects concerning student and teaching actions addressing their learning needs (KSSE, KTSE; KCT-SE), the questions of mathematics preservice teachers refer primarily to content and teaching (MKT). Nevertheless, we did find evidence of the integrated M-SEPACK knowledge in each question/response for categories 2.4, 2.5, and 2.6. We interpret this finding as evidence that the consultation template (Table 2) does provide opportunities for mathematics and special education preservice teachers to integrate their respective knowledge bases. These results provide one piece of promising evidence that this intervention for preservice teachers in the university classroom may indeed increase future teachers' abilities to consult to meet the needs of students with special education needs.

Study 2 Summary: United States – Engaging Preservice Teachers in the Mathematics-Specific Consultation During a Linked Course and Field Experience

The study that took place in the United States used the same consultation template (Table 2) as the study in Germany. To complement the German team's overall analysis of the types of knowledge that emerged in their university-based approximations of consultations, the United States team provides an in-depth look at one consultation case between a special needs education preservice teacher and an elementary education mathematics preservice teacher engaged in fieldwork at a local elementary school. This provides an in-depth look at some of the nuances in the type of knowledge that is co-created within the consultation space.

Methods

This implementation study was conducted in the context of teacher preparation programs at a large teaching and research university in the southern United States. The participants were 16 special needs education preservice teachers and 14 elementary education mathematics preservice teachers. The special needs education preservice teachers were enrolled in an undergraduate mathematics methods course that was part of programs for both the special education and mathematics preservice teachers. The mathematics preservice teachers were concurrently participating in a full-time internship (fieldwork) for which they were working in elementary classrooms alongside full-time elementary school teachers. The mathematics preservice teachers were asked to identify a student in their classroom who had been identified as having a special education need. They then conducted a cognitive interview (Hunting, 1997; Moyer & Milewicz, 2002) with the student and took notes regarding the student, the classroom environment in which he/she was learning, and the specific mathematical content the student would be learning (STEP 1 of Table 2).

The two preservice teachers then met and discussed the student, their learning needs, and the other information the mathematics preservice teacher garnered from the interview. After this, the special needs education preservice teacher researched the student's specific learning needs and provided a written response to the mathematics preservice teacher's questions that included recommendations for working with the target student. The two preservice teachers then met again to discuss the recommendations and created a plan for teaching the specified mathematics to the target student. Next, the mathematics preservice teacher implemented the plan, collected evidence regarding how the student responded to the implementation of the plan, and shared this with the special needs education preservice teacher. Both preservice teachers then reflected on the student, the recommendations, the implementation of the plan, and the overall process.

Findings

For purposes of this paper, we discuss the findings from one of the 14 consultation teams to provide a qualitative illustration of the mathematics-specific consultation process and its impact on two preservice teachers— the mathematics preservice teacher Charity and the special needs education preservice teacher Gabriella (pseudonyms). We analyzed the questions and recommendations generated by the two preservice teachers and the types of specialized knowledge each question or recommendation represents.

Charity had noticed that Edward, one of the students in her kindergarten classroom, was struggling with counting and number sense. Edward was six years old, had already been diagnosed as having Attention Deficit Hyperactivity Disorder (ADHD), and was taking medications for this condition. After conducting a cognitive interview to understand which specific standards were difficult for Edward, Charity filled out the consultation template. When the template (2.4) prompted Charity to ask a question about the student and their exceptionality (Knowledge of Students and Special Education), she instead asked "How can I increase engagement when the student is in a group setting?" (Knowledge of Teaching in Special Education). Instead of following the prompt to better understand the *student* this preservice teacher wanted to jump right to focusing on her own teaching actions. Then, when the template (2.5) prompted Charity to ask a question about teaching actions to promote content learning for this student (Knowledge of Content and Teaching-Special Education), Charity instead asked about general teaching strategies: "Once he masters the objective, what are some ways to allow him to stay engaged and not distract other students from learning?" We suggest that this sheds light on how difficult it is for the preservice teachers to keep the content of mathematics at the center of the consultation.

Despite the fact that Charity didn't maximize her opportunities to ask questions related to M-SEPACK, her special education consultant Gabriella still provided key information about how ADHD might be interacting in unique ways with Edward's actions in the mathematics classroom. Gabriella backed up her teaching recommendations with a research article that Charity found to be very useful in modifying her teaching for Edward. Charity was able to provide tactile number sense activities with snap cubes and intermittent opportunities to use fidget toys in order to keep Edward engaged for short bursts of number sense learning. After the classroom implementation, Charity noted, "the article that was shared provided me with a lot of beneficial information. I will continue to incorporate this strategy into my classroom practice in the future." After reflection upon the consultation process, Gabriela noted how much she learned about the consultation process in general and how she learned that the elementary education teachers "are very eager to learn about this topic (special education strategies for mathematics)."

We share this case because we believe that it simultaneously illustrates the difficulty preservice teachers encounter when learning how to engage in content-specific consultations, and also the benefits to preparing them for this complex practice. Our research team is also engaged in multiple follow-up studies to further understand the impact of this method of preparing preservice teachers to engage in mathematics-specific consultation.

International Discussion and Implications

The focus of this paper is on an international collaboration among teacher educators/researchers from four universities in four different countries, Brazil, China, Germany, and the United States, who are engaging in a common research and teacher preparation purpose – how the mathematics-specific consultation can positively impact general education and special education preservice teachers to work together to generate the M-SEPACK needed to teach effectively for students with special education needs. An important aspect of this work is how our collective and unique perspectives and experiences can enhance what is learned through our international research collaboration, and in this way, we have both a s*hared but given goal* and a *shared beyond given goal* (Quebec Fuentes & Spice, 2017; Quebec Fuentes & Bloom, 2021). Therefore, we found it to be important that the voices of researchers from all four countries are included in the discussion even though the case summaries were based on data from two of the four countries in this international collaboration. In this section, the teacher educators/researchers from each country share their reflections on the findings of the two studies described in the case summaries above. The paper concludes with our thoughts about the implications of this work.

Brazil

In Brazil, there are frequent calls by both education professionals and researchers for co-teaching and coaching situations involving special education professionals. This collaboration typically takes the form of a general education teacher receiving help from a special education teacher, (which can be either from the same school or a guest specialist). This often results in a hierarchical dispute over knowledge, and usually the responsibility for student learning ends up falling solely to the special education specialist.

The consultation model used in the German and Unites States studies may address some of the issues found in other forms of teacher collaboration by favoring a more equitable sharing of power in the relationship of the preservice teachers. In this case, both act with the same goal. The examples presented by the researchers conducted in the United States and Germany demonstrate that the consultation model can be adopted by different cultures and adapted to reflect the unique aspects of each country's context. Many Brazilian studies corroborate the German research indicating the focus of the regular classroom teacher with content, the attention of special education teachers with content, and students' unique learning needs. As the United States research points out through the case of Charity and Gabriella, consultation can foster a practical, evidence-based learning that has proved quite useful in their professional performances, something that traditional teaching methods have not been able to achieve.

In Brazil, most of the work in special education happens due to partnerships between a university and other education networks. In the past, these networks have concentrated their research on elementary inservice teachers. Based on the findings presented here, we suggest that work with preservice teachers can promote innovative exchange between teachers, technicians and students, and that these can contribute to the advancement and strengthening of our schools' specialized human resources.

China

Although we do not yet have sufficient empirical evidence on how to prepare preservice teachers to engage in collaborations in China, the consultation template has been shown in Germany and the United States to provide preservice teachers with good opportunities to collaboratively address the specific learning differences of students with special education needs. From the German study, we conclude that the consultation process appears to make a sustainable contribution to preservice teachers' preparation for inclusive teaching. However, we recognize that there will be some difficulties implementing consultations in university courses. It is important that course instructors gain experience engaging in the consultation process themselves so that they have the knowledge necessary to support this type of content-specific consultations. For preservice teachers, additional time may be needed to introduce the template and explain the steps during the university course. When implementing the co-constructed plan, the preservice teacher may need additional support balancing the need to engage in consultations while simultaneously attending to the full-time compulsory education mathematics curriculum standards in China and incorporating the U.S. Common Core Standards for Mathematical Practice (CCSSO, 2010) (Question 2.6 of Table 2).

Germany

The transfer of the template, created by the United States team, to the German University X has offered preservice teachers an opportunity to collaborate and to take a deep look at how to meet the learning needs of individual students. This appears to be a sustainable contribution to prepare preservice teachers for inclusive teaching. Nevertheless, there were and are difficulties within the implementation in the university course. The interaction with the preservice teachers during the preparation for the consultation revealed that it requires a substantial amount of time to explain the many steps of the template. Additionally, some of the preservice teachers' questions and difficulties in engaging in the consultation process may be a result of translation issues from English to German. Other difficulties may be caused instead from a different conceptualization of students' competencies in the U.S. Common Core State Standards for Mathematics (CCSSO, 2010) and the German conceptualization in the governmental "Bildungsplan". Nevertheless, the preservice teachers felt that demonstrating the consultation process in the form of role play was very helpful. Based on our experience, we suggest that more time should be used to introduce the template during the university course.

United States

Considering the German study of mathematics consultations, as well as the work we have done in the United States, there is much that United States teacher educators can apply to their contexts. The work by the German teacher educators included the use of role playing to help prepare their preservice teachers to engage in consultations. This type of approximation of practice, also referred to as "rehearsals", has been used to prepare novice mathematics teachers in other aspects of their work (Lampert et al., 2013). As noted in the case highlighting the work in the United States as well as our initial work with mathematics consultations (van Ingen et al., 2016), the focus on the mathematical content is often lost as the two consultants get drawn toward a discussion of general teaching practices. Engaging consultants in role-play of a consultation, as was done in the German study, would provide teacher educators the opportunity to provide feedback related to this and may help the consultants to keep a focus on the mathematical context along with a focus on the student's learning needs.

Both the German and United States examples of mathematics-specific consultations involved work being done with preservice teachers at the elementary school level. How might this work be similar and what differences would there be if the consultations were for teachers working at the secondary level? One of the authors has begun an initial exploration into these questions (Eskelson & Hughes, in preparation). Initial analyses indicate that preservice teachers at the secondary level also struggle to maintain a focus on mathematics during the consultation. As with their counterparts teaching elementary grades, the consultations often slipped back to a more general discussion of teaching and students. Additional research should explore how the important differences between teaching elementary and secondary mathematics might impact teachers' engagement in mathematics consultations and teacher educators' efforts in engaging teachers in this work.

Implications

Based on the findings we have presented from two cases of the mathematics-specific consultation implementation in two countries, and the reflections on those implementations from four different countries, we believe that the consultation template shows promise for being a helpful tool to prepare preservice teachers for opportunities in which they can leverage their respective areas of expertise to generate the M-SEPACK needed to teach effectively for students with special needs. Across countries and contexts, the mathematics-specific consultation template has provided an opportunity to help general education and special education preservice teachers learn how to engage in content-specific conversations. The template provides preservice teachers with the opportunity to integrate their respective knowledge bases and generate a teaching plan that is specific both to the mathematics being taught *and* to the unique special education needs of a specific student. With that in mind, the template and the consultation can be seen as an opportunity to bring different disciplines together and to broaden preservice teachers' perspectives on the advantages of interdisciplinary collaboration.

Each of our four research teams, spread across four continents, has benefited greatly from the opportunity to consider the commonalities among our contexts (*shared but given goal*) as well as the unique differences (*shared beyond given goal*) (Quebec Fuentes & Bloom, 2021; Quebec Fuentes & Spice, 2017). Our international research collaboration has pushed each team to consider its own work in teacher preparation from different angles. We recognize that the need to prepare teachers for inclusive classrooms is truly a global imperative. Rather than attempt to solve this problem in isolation, we are exploring the boundaries of our similarities and differences in seeking a common solution. We recognize that in studying the role of context in the consultation template, each of our four teams will develop a more nuanced and flexible approach to the work that we do in our own countries. Furthermore, it is our hope that this shared international research agenda will ultimately produce a robust knowledge base of a practice that can be leveraged globally to push the field forward in our shared priority to prepare preservice teachers for meeting the needs of *all* students.

There is a great deal of further research to be done on preparing preservice teachers for mathematics-specific consultations. In this paper, we have begun to explore what the preservice teachers preparation intervention (use of the consultation template) looks like in two different countries and have begun to examine the types of knowledge that preservice teachers have generated in the consultations. In future studies, we will test this intervention with larger sample sizes and across additional settings. Preparing preservice teachers to engage in mathematics specific consultations to meet the needs of special needs students and researching how this can best be done internationally is a complex undertaking. This work not only requires expertise from multiple education disciplines (i.e., mathematics education and special needs education), it also requires understanding different international contexts, preservice teacher education certification/credentialing requirements, and the nuances of the mathematics curriculum for individual countries. The promise of this area of research is that through continued international collaboration, we will gain deeper understanding of how mathematics specific consultations can promote the mathematical success of special needs students across countries and cultures. Through our preliminary work, we have begun to actualize this promise. For example, we have found that utilizing role-play as a method of modeling the mathematics specific consultation process for preservice students is an effective practice for initially engaging students in the process. Both the German and United States teams have utilized role-play in both case teaching and application of the mathematics consultation process for actual special needs students during preservice teachers' clinical field experiences. We have also observed that the mathematics specific consultation process provides both mathematics preservice teachers and special needs education preservice teachers experience in how professionals with both similar and different areas of expertise can equitably contribute. This occurs by addressing the needs of special needs students rather than the traditional mindset that one professional's expertise is more important than another's leading to teachers teaching is silos rather than collaboratively. Barriers include finding the instructional time needed to integrate teaching the mathematics specific consultation within existing university course curricula/coursework. For example, we agree that more time is needed to initially introduce the steps of the mathematics specific consultation process in order for students to implement the process with more fidelity. An important outcome of mathematics specific consultations is to engage teachers in more in-depth and targeted discussions about the mathematics learning needs of students. The data suggest that this occurred at different levels within and across the German and United States studies. It is important that we continue to develop and test out new ways to coach preservice teachers to utilize their common and unique areas of expertise to move from more general to more targeted and in-depth consultation discussions. Finally, we wonder how the mathematics specific consultation can be applied at both early childhood and secondary levels and how it may or may not need to be differentiated compared to its implementation at the elementary level.

Teacher educators around the globe who are reading this article and who are interested in preparing preservice general and special education teachers for collaboration, can use the consultation template documented in this article along with the knowledge gained from the brief reports and reflections to plan for their own implementations of preparing preservice teachers to engage in mathematics-specific consultations. This article both reflects upon and launches a global conversation about one specific way in which teacher educators can prepare preservice teachers with consultation skills to teach in the global era of inclusion.

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A Book Review of Erin Marie Furtak's *Formative Assessment for 3D Science Learning: Supporting Ambitious and Equitable Instruction*

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BOOK INFORMATION

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Book Review

Formative Assessment for 3D Science Learning: Supporting Ambitious and Equitable Instruction, by Erin Marie Furtak, a former high school science teacher who now studies how science educators can improve their instructional practice through the use of formative assessment, presents an up-to-date look at how K-12 science educators can use formative assessments in their classrooms to provide educational equity and justice within the context of three-dimensional science learning experiences. Throughout the book, Furtak uses the concept of a "formative assessment activity system," which she has adapted from Engeström (1987, 2001) and Gee (2008) in which instruction and assessment, particularly formative assessment, take place. This formative assessment activity system is one that "encompasses tasks, processes, and more" that are utilized in a science classroom that work together to lead to the desired outcome of supporting and advancing students' science learning (p. 23-24). Furtak's stated goal is to "integrate research…to provide evidence for different approaches, as well as rich examples…that weave together literatures to push the conversation in science formative assessment to a new place" (p. xvii). The book is divided into three parts: framing, design and enactment within classrooms, and professional learning.

Part one of the book, Framing, contains three chapters that examine formative assessment in its past, present, and potentially future forms. Furtak invites us to "broaden our view" of formative assessments as they are traditionally used in science classrooms. She argues that we can utilize formative assessment systems to provide equity and justice for all students by shifting the focus from simply the tasks themselves, and students' immediate interactions with them, to a more holistic view that allows for more interactions, multiple voices, and the historicity of the activity or task as experienced by the students. By taking the wider view, the goal of science instruction can shift from just content knowledge to students engaging in the practices of science, which would allow formative assessments to usher in educational equity and justice as students can share their science knowledge using a variety of methods.

Part two of the book, Tasks and Practices, contain four chapters that break down four steps leading to a successful formative activity system (phenomena selection, the tasks themselves, classroom enactment, and feedback). She walks through how a classroom educator can begin the process of shifting their formative assessment focus from gathering data on the accumulation of knowledge to pushing students to further their science understanding more deeply. When the four steps are implemented, students are provided the opportunities to engage in the science practices. These chapters include a plethora of examples of formative assessment tasks that teachers have implemented in their classrooms as part of Furtak's research. Part three, Beyond the Classroom, contains three chapters that provide insight into how professional teams can begin designing and using their own formative assessments. This includes how to use the data gathered, along with the learning progressions either from the *Next Generation Science Standards* (NGSS) or curricular materials, to advise the classroom system.

The book does an excellent job outlining current research on science learning and teaching in the wake of the adoption of the NGSS (and the ongoing efforts to implement its vision), while still remaining accessible to a practitioner audience. Whether a classroom teacher, non-educator, or administrator reads this book, the research basis of the book is clear, but not overwhelming. That research base lays the foundation for the practical pieces that follow. As a K-12 science educator who has struggled to shift my instructional practice to align with the vision of the NGSS, I appreciated this book and its evidence-based examples that were from classrooms around the United States. Furtak's proposal to shift our assessment focus from the accumulation of knowledge by students (focusing on the NGSS Disciplinary Core Ideas) to providing them opportunities to demonstrate their proficiency of Science and Engineering Practices is, in my mind, the missing piece needed to make the final leap to a classroom that is daily working toward the vision of the NGSS. The information and ideas presented by Furtak are almost immediately usable, which is a welcome sight for the ever-stressed science educator.

One of the themes throughout Furtak's book is the claim that rethinking our approach to formative assessment in science will provide for a more equitable and just science education for all. I find this claim compelling and very well supported throughout the book. By providing students with tasks that are related to phenomenon that they might already have some experience with, all students are provided a means to begin with some of their own ideas. As tasks are developed and implemented, students are given the opportunity to convey their understanding along the way in whatever means they find most beneficial. Implementing a formative assessment system as Furtak describes, and some recently published curricula include, ensures that all students regardless of their background, have access in a way that likely does not exist in more traditional assessment systems.

I see this book as being appropriate for both an in-service teacher audience and a pre-service teacher audience. For in-service teachers working to implement the NGSS in their own classrooms, this book offers plenty of text with which we could reflect on, and even critique, our own practice. Changing long-established practices is no easy task and Furtak provides a pathway to at least begin having those conversations with colleagues. Pre-service teachers can also benefit from this book as part of their teacher preparation program. As they are learning about the NGSS and the vision laid out in the *Framework*, this book can offer them a foundation to begin considering how they will work to assess student science understanding in their own classrooms in the future. If they entered the profession with a vision for how they would like to assess science learning, hopefully they would be less likely to not fall into the way things have always been done.

As a K-12 science educator, I know that we engage in our practice within the confines of an educational system that does not seem quite ready to let go of the ways of the past, including the century-old practice of assigning grades. And while Furtak does a remarkable job of outlining the research and rationale behind the necessity of a pedagogical shift, I was hoping to get more of a sense of how this translates to the nitty-gritty of determining student understanding that could translate to a grade. Yet a discussion of how formative assessments and their proper implementation fit into the larger mechanism of a school's or classroom's grading scheme, if at all, seems necessary for teachers to begin altering long-established practices. A welcome addition to the book would be more connections to the messier side of implementation, specifically grades and how this works with students who are not used to these types of assessment.

Overall, Furtak presents a well-researched and supported argument for revamping our ideas of formative assessments and how they can provide an equitable and just science learning experience for all students. *Formative Assessment for 3D Science Learning* is a readable and valuable resource for educators looking for research-based strategies on NGSS implementation, as well as examples of what science educators around the United States have done in the decade since the release of NGSS. Furtak hopes that the book "allows us to step back to view the larger systems influencing what is possible in assessment, as well as mechanisms to both interrogate and change the current state of practice" (p. 179). I believe that she has provided a resource for classroom educators that can be the impetus for exactly that.

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