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Data Availability

The datasets generated and analyzed during the current study are not publicly available due the fact that they constitute an excerpt of research in progress but are available from the corresponding author on reasonable request.

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School mathematics curricula in the United States often exist with distinct boundaries between subjects. This traditionally compartmentalized framing may lead learners to have a very limited view of the true depth and utility of mathematics. We view mathematics through a Deleuzoguattarian lens of rhizomatic interconnectedness (Deleuze & Guattari, 1987/2007). In a rhizomatic system, everything is linked with no clear beginning, middle, or end. The theory of Expansive Framing, which characterizes learning as a series of interrelated, overlapping ideas, applies this notion of rhizomatic systems to education and provides a way to conceptualize transfer between systems. When content is framed expansively – across contexts, spaces, and times – learners may be better able to make broad connections to other ideas and ultimately transfer that content outside of the classroom. In this research report, we discuss the theory of Expansive Framing and its application to an interdisciplinary mathematics-computer science curricular unit.

Expansive Framing Theory and Connections to Prior Research

At its core, Expansive Framing is a theory that helps to explain and facilitate transfer, so a comprehensive investigation into the theory must necessarily begin with an investigation into transfer. Transfer can be broadly defined as the generalization and application of learning from one situation to another. For example, a person may transfer (or not transfer) their learning of geometry principles to their painting of a landscape, or their grasp of fractions to a musical composition. Transfer is the paramount goal of education (Roberts et al., 2007), and has been characterized as “the beating heart of intellectual agility” (Northeastern Center for Advancing Teaching and Learning Through Research, 2019). Though transfer is an extensively studied construct, it remains elusive and divisive (Barnett & Ceci, 2002; National Research Council, 2000), with “little agreement in the scholarly community about the nature of transfer, the extent to which it occurs, and the nature of its underlying mechanisms” (Barnett & Ceci, 2002, p. 612).

Expansive Framing acknowledges the transfer debate but reconceptualizes transfer from a situative and sociocultural perspective, supporting the notion that content knowledge and context of use are linked (Catambrone & Holyoak, 1989). Framing is defined as “the meta-communicative act of characterizing what is happening in a given context and how different people are participating in it” (Engle et al., 2012, p. 217). When learning experiences are framed in a bounded manner, there are no connections made outside of that experience, which discourages transfer (Engle et al., 2012). In contrast, expansively framed encounters foster student authorship of their own learning (Lam et al., 2014) and encourage connections across contexts. Expansive Framing posits that transfer between systems is more likely to occur when topics are framed widely: across time, setting, and context (Engle, 2006), and offers a way to continue studying and facilitating the elusive construct of transfer. The research questions guiding this study were 1) *In what ways is Expansive Framing applied in the mathematics-computer science lesson plans, and 2) how are expansively framed content and context carried over into instruction?*

Research Approach and Data Sources

The data in this study are part of a larger Research-Practice Partnership project on supporting paraprofessional educators and teachers in rural schools in the intermountain west to provide effective and equitable computer science (CS) education to all elementary students in the district. The research-practice partners in this project formed a Design Team of fifth-grade teachers, paraprofessional educators who teach CS in the computer labs, district specialists, and university researchers that collaboratively design units around connected core ideas in CS and math. In this pilot project analysis, we focused on how Expansive Framing as both a theory and an instructional method is explicated in the interdisciplinary lesson plans, and to what extent expansively framed content and context are carried over into instruction by focusing on two classroom spaces: a mathematics classroom, led by an elementary teacher, and a computer lab, led by a paraprofessional Computer Lab Specialist (CLS).

Data were from four sources: 1) a mathematics lesson plan (Math Lesson #3: Conditionals and Regular/Non-Regular Polygons), 2) the accompanying transcript from Math Lesson #3's enactment in Mrs. W's classroom, 3) a computer lab lesson plan (Scratch Card: Quadrilaterals), and 4) the associated transcript from the lesson enactment in Mrs. A's computer lab with Mrs. W's fifth-grade students. In these lessons, students learned to classify polygons using conditionals (a computer science concept) and programmed a geometry-themed game in Scratch, a block-based computer coding platform.

We employed a grounded theory approach to analyze the data. After combing through the data sources and recognizing that Expansive Framing (EF) can be characterized as both a theory of learning transfer and an instructional approach, two main codes emerged: EF as theory and EF as instructional technique. The parent code EF as theory was further broken down using three transfer measures defined by Engle et al. (2011): transfer of knowing (application of something *already known* from one system to another), transfer of learning (application of something *recently learned* from one system to another), and transfer after exposure (application of ideas *after exposure* to similar ideas from a related system). The parent code EF as instructional technique was also broken down into sub-codes content, context, promoting student authorship, and bounded framing. Because Expansive Framing is a theory that focuses on contextual framing, we compartmentalized the context component even further using Barnett & Ceci's

(2002) taxonomy of context transfer: knowledge domain (knowledge base to which content is applied), physical context (location), temporal context (time), functional context (mindset and function to which learning is applied), social context (groups of people), and modality (format of learning). Data sources were coded using HyperResearch software.

Findings, Conclusion, and Significance

Three major themes emerged: framing of content, framing of context, and transfer facilitation. *Framing of content* describes how well and how frequently content is framed expansively or boundedly across spaces. *Framing of context* illustrates ways teachers engage in framing context expansively or boundedly, and how student authorship is promoted across spaces. Finally, *transfer facilitation* describes how often transfer of learning, transfer of knowing, and/or transfer of exposure are promoted across and within classrooms.

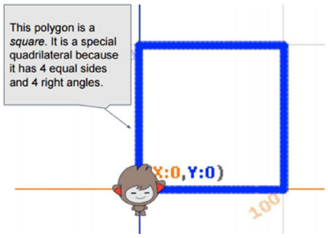
Theme 1: Framing of Content

Expansive Framing emphasizes that content does not exist independent of context; however, this theme focuses primarily on framing of content. The data revealed several instances of both expansive and bounded framing of content across classrooms. In the math lesson, polygon classification was framed expansively through the use of conditional statements, which are also used in computer programming. For example, students were given the prompt, "*If* a quadrilateral is regular, *then* it has four ____ angles, *else* it is _____", and asked to work with partners to fill in the blanks to create the correct statement, "*If* a quadrilateral is regular, *then* it has four <u>congruent</u> angles, *else* it is <u>not regular</u>." The if, then, else format mirrors conditional statements the students used in the computer lab. The lesson plan also provided the teacher with the following short statement to guide their expansive framing of content: "In computer programming, these [if, then, else statements] are called conditional statements, but as we've seen in class today, conditionals can also be used to classify shapes." In the lesson enactment, Mrs. W framed content expansively using the provided lesson plans, but no additional impromptu expansive framing of content occurred.

The computer lab lesson plan Scratch Card: Quadrilaterals featured multiple cross-curricular features that framed content expansively. All of the programming that students completed in this lesson required students to use the content they had learned in mathematics class about properties of polygons and quadrilaterals. Figure 1 shows a screenshot from the lesson in which students programmed their "sprite" (character) to draw a square. The callout text reminded students of the special properties of a square that they initially learned in mathematics class and were revisiting within a computer coding environment.

Figure 1

Expansive Framing of Mathematics Content in the Computer Lab Lesson Plan

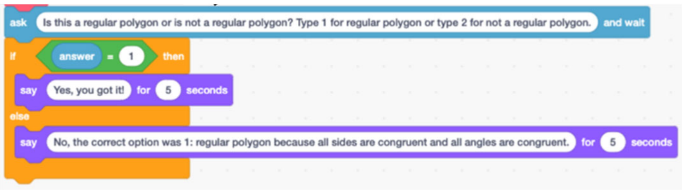


This polygon is a *square*. It is a special quadrilateral because it has 4 equal sides and 4 right angles.

Additionally, students were prompted to use conditionals, which were also employed in the mathematics classroom, to complete their coding in the computer lab. As shown in Figure 2, the orange block consists of an if, then, else (conditional) statement and students must fill in the blanks to program a quiz question based on the properties of polygons.

Figure 2

Use of Conditionals in Computer Lab Lesson Plan



```
ask (Is this a regular polygon or is not a regular polygon? Type 1 for regular polygon or type 2 for not a regular polygon.) and wait
if <(answer) = (1)> then
  say (Yes, you got it!) for (5) seconds
else
  say (No, the correct option was 1: regular polygon because all sides are congruent and all angles are congruent.) for (5) seconds
```

During the computer lab implementation of the lesson, Mrs. A led the lesson on the projector and the students followed along on their own computer. Aside from a few mentions of mathematics class ("We're going to do our quadrilateral lesson because you guys have been learning about what in math class?"), the emphasis was on procedural skill in Scratch:

> *Mrs. A*: So our question is, is this a rectangle, or a square, so now, I've already added this in for you, we have to say, give two answers. And it's going to determine if you choose right or wrong. So the one that says say, Yes, you got it. We're going to put it as the very first so if answer equals one, then you got it right…Okay, so I'm going to put that right there and quickly, make sure that yours looks the same as mine.

While the lesson plans included many instances of intentional expansively framed content, it seems that this framing of content did not necessarily carry over into instruction.

Theme 2: Framing of Context

Expansive and bounded framing of context was also found in every artifact. Math Lesson #3 made expansive connections across knowledge domains, physical contexts, temporal contexts, and social contexts. For instance, the line from the lesson plan, "You'll make a game in the computer lab and will need to use conditional statements," connects physical environments (math classroom to computer lab) and temporal contexts (you *will* make a game). The statement, "In computer programming [if, then, else statements] are called conditional statements, but as we've seen in class today, conditionals can also be used to classify shapes," served to frame context across knowledge domains (mathematics and computer science).

In the math lesson enactment, Mrs. W created additional contextual connections beyond what was provided in the lesson plan. She framed context expansively across social systems by referring to the computer lab teacher Mrs. A, and encouraging students to work in partnerships to explain their thinking. Spontaneous contextual framing also occurred across modalities ("Oh, is that following the same pattern that we looked at in the other [questions]?") and temporalities ("When you are in the computer lab this week, on Friday…"). Mrs. W also promoted student authorship through her questioning strategies (“Can you explain what you mean by that?”). Though infrequent, some instances of bounded framing were also found in closed-ended statements such as, “Today we’re talking about conditionals and regular polygons.”

The computer lab lesson framed context expansively, with almost all contextual framing focused on knowledge domain. For example, students completed a task to code a sprite to draw a parallelogram, which frames context across knowledge domain (mathematics and computer science). Educative elements such as callout text with properties of quadrilaterals were added to prime students’ mathematics knowledge, demonstrating expansive framing across knowledge domains.

In the computer lab enactment, Mrs. A began by framing expansively across physical contexts by saying, “Were going to do our quadrilateral lesson because you guys have been learning about what in math?” She made several references to the coordinate plane, a concept that students had learned previously, but Mrs. A did not call direct attention to the main mathematics focus of the lesson (properties of quadrilaterals), leaving students to make those connections through use of the educative elements on the instructional cards themselves. Mrs. A did not make any direct references to the properties of quadrilaterals during the classroom enactment outside of the intercontextual framing in the lesson plan itself.

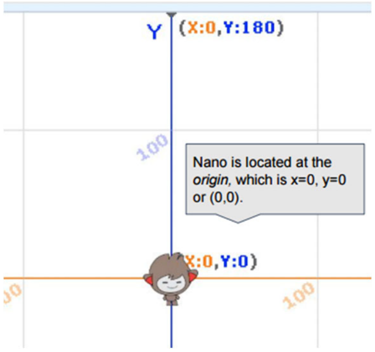
Theme 3: Transfer Facilitation

The theme of transfer facilitation speaks to the notion of Expansive Framing as a theory, not simply as an instructional approach. It is important to note that, based on the available data, student transfer across systems is impossible to identify as having definitively occurred (Barnett & Ceci, 2002). Instead of presuming recognition of transfer, we instead found evidence of transfer being *facilitated* either explicitly through the lesson plan or via impromptu connection-making as supported by the instructor. In the mathematics classroom, transfer was fostered more frequently during the implementation as compared to explicated in the lesson plan. One case of facilitating transfer of learning was noted in the math lesson plan where students were asked to identify similarities and differences of various shapes in a Venn diagram. The discussion was intended to foster transfer of learning, where students were expected to call upon recently learned content and transfer it to a new classification system. During the classroom implementation of the lesson plan, Mrs. W's additional prompts fostered transfer of knowing and transfer after exposure. Mrs. W not only used the Venn diagram activity to facilitate transfer of learning, but also prompted transfer of knowing in her cues relative to Venn diagrams (e.g., "Remember a Venn diagram? It has circles and the two sides are what each one has in common and the middle is what both have in common, do you guys remember that?").

The computer lab lesson featured several educative notations intended to cultivate transfer across systems. Figure 3 shows a portion of the instructional cards for students that contain an educative callout referencing the origin at the point (0,0).

Figure 3

Educative Callout Referencing the Origin in the Computer Lab Lesson Plan



Nano is located at the *origin*, which is x=0, y=0 or (0,0).

In this lesson students were tasked with writing code that makes the sprite draw specified quadrilaterals and other polygons. While the main objective of the lesson was to use conditionals to identify features of various shapes, the coordinate plane also plays a role in the lesson.

Students learned about the coordinate plane earlier in the school year and were required to call upon that knowledge to direct the sprite to specific locations on the grid. Mrs. A helped facilitate transfer of knowing through statements such as:

> *Mrs. A:* "Okay, so let's think of drawing a rectangle. Let's think about if we had a pen and our paper with our grids. How are we going to draw a rectangle? Where are we doing to start? Okay, (100,0). ... So, we're going to start our x-coordinate at 100. And we're going to go to the y, at zero."

Again, while student transfer is not implied, there is evidence in both classrooms that teachers used Expansive Framing instructional techniques to help foster transfer across and within systems.

Conclusion and Significance

Applying Expansive Framing as a lens to study these data sources allowed clear identification of several instances of facilitation of transfer by expansively framing across content and context. In the case of the computer lab lesson, framing was found to be more expansive in the lesson plan versus the classroom implementation. However, in the mathematics classroom, more expansive framing of context was present in Mrs. W's implementation as compared to what was explicated in the lesson plan. We plan to analyze the data from other lessons and other classrooms to determine if these patterns continue or if other patterns emerge.

The purpose of this paper was to review the literature on Expansive Framing and apply the theory to a data set to understand the ways Expansive Framing is applied to lesson design and instruction. By applying Expansive Framing to mathematics education and curriculum design, we can reopen the discussion on transfer, portray content as interconnected and overlapping, and foster broad connection-making, which will help our learners to view the world as a rhizomatic network of knowledge that exists among various learning domains.

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