CULTURALLY RELEVANT COMPUTING TASKS: EVIDENCE OF SYNERGIES BETWEEN STUDENTS' MATHEMATICAL AND COMPUTATIONAL THINKING

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In this study, we explore the synergies between students' mathematical and computational thinking as they engage in an open-ended computing "Quilts" project. The activity aims to create a culturally relevant learning environment in which students have opportunities to code personalized quilts that demonstrate their culture and values. An open-coding process was used to analyze team projects. The results of the study suggested that the computational medium gave students flexibility to devise multiple design plans using the power of mathematics and opportunities to test their chosen approaches. Some of the plans included defining functions, using geometric transformations and estimating coordinates. The code provided insights into the students' familiarity with mathematical concepts, level of abstraction and precision in their calculations. Each team created unique quilts that demonstrate multiple values such as freedom, equity and personal life experiences such as music, family, and homeland.

Keywords: Computational Thinking, Mathematical Thinking, Culturally Relevant Pedagogy

Culturally relevant pedagogy (CRP) (Ladson-Billings, 1995) has been used to create engaging and personally relevant learning opportunities, in particular for traditionally underserved and marginalized students (Enyedy & Mukhopadhyay, 2007). CRP not only focuses on students' achievement in a learning environment. It also supports students' development of critical consciousness about inequities while acknowledging and accepting their cultural identity (Ladson-Billings, 1995). In this study, we explore the synergies between students' mathematical and computational thinking as they engage in an open-ended computing "Quilts" project. In the project, students express their values and thoughts by designing their own quilts as a team, using the flexibility of a computing medium and the power of mathematical thinking.

A growing number of studies is exploring the connection between computational thinking and mathematics learning (Barcelos et al., 2018). The majority of these studies mainly focused on teaching programming skills with a limited or no explicit connection to key mathematical ideas and concepts (Hickmott et al. 2018). A limited number of recent studies (e.g. Alegre et al., 2020; Schanzer et al. 2015) explore the connection between mathematical and computing concepts. However, few studies use culturally relevant computing tasks. Aligned with Li et al. (2020)'s perspective, we believe that computational thinking is more about thinking than computing. This study will present examples of how students used various mathematical strategies as they code personalized quilts that reflect their own values, lives and cultures.

Method

We analyzed the data gathered from the end of year Cultural Quilts project of the year-long Introduction to Computational Thinking (ICT) course that is designed to foster 9th graders' understanding of mathematics and teach programming. The quilts activity aims to create a culturally relevant learning environment in which students have opportunities to code personalized quilts. This activity also enables them to demonstrate their programming skills and use mathematical knowledge such as geometric transformations, and functions.

The activity has 3 phases. In the first phase, students research about the history of quilts and reflect on the relevance of quilts in American history (e.g. quilts have been used to carry over traditions across generations). In the second phase, students work in teams to design a quilt that has a common theme but is made by patching several patterns together. The theme represents values that are important for the team. In the third phase, each student needs to create a geometric pattern and decorate it with symbols related to the values chosen by the team. Finally, all the decorated patterns made by each team member are put together in a single quilt design, and the students write a reflection on how the final quilt is related to the chosen values.

To design quilts, students used CodeWorld, which is an integrated coding platform designed for young students, where the code is based on constructing basic shapes (polygons, circles) and performing geometric transformations (translations, rotations, scalings) on them. These simple instructions can be combined to create very elaborate designs.

Data Sources and Analysis

We collected the data from 352 projects from students in 14 different schools. The data set included code of 1) selected symbols and geometric shapes 2) each team members' pattern (a patch of the whole quilt formed of geometric shapes and symbols) and 3) team's final quilt. It also included the theme of the final quilt and a written description of the values, culture and life demonstrated in the quilt. Two researchers engaged in an open-coding process (randomly selected half of the projects) to identify the mathematical strategies being used in the code and the major themes in students' descriptions.

Findings

In the initial phase of dynamic quilts design, the majority of the students used mathematical estimation to decide how to partition the output window, where to place their geometric shapes and symbols to create their individual patterned patch. A few students used precise mathematical calculations in this process. Figure 1 shows an example for both approaches.

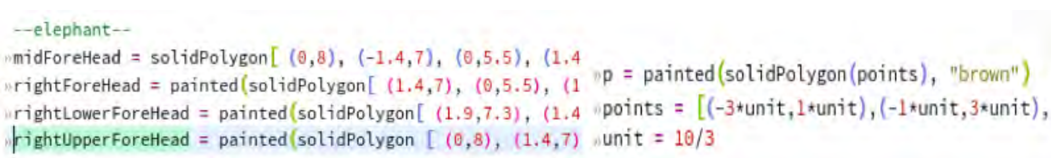

Figure 1: Mathematical estimation (on the left) and precise calculation (on the right)

As they created their quilts, students used various mathematical strategies such as 1) define function(s) to construct repetitive patterns (24%), 2) use geometric transformations to set positions relative to other object(s) (37%) 3) create each object systematically (e.g. by defining its coordinates considering their size, output size etc.) (22%) 4) create objects unsystematically (e.g. by defining its coordinates without considering the locations of the other objects) (17%). In some codes, they used multiple strategies. The elegance of their code varied depending on the mathematical approach students used to create objects and patterns. Figure 2 shows an example of how one team (3 students) used the first strategy while creating an object (a pattern formed by geometric shapes) for their quilt.

```
s71 = combined[s(0,"red"),s(1,"green"),s(2,"yellow"),s(3, "blue")]
    where
    s(r,c) = painted(rotated(translated(rotated(solidRectangle(8,8), 45),
                                        (u62,u62)), r*90), c)
    u62 = 67/24
```

Figure 2: Creating an object by defining functions

To create the object in figure 2, students defined a function, s, that takes a rotation index (r) and a color (c). In the definition of s, the construction starts with an 8x8 square, which is rotated 45 degrees, then translated, then rotated again by a multiple of 90 degrees given by the argument r, and finally painted in the given color c. The squares are created in the order given in the first line of the code (red, green, yellow, blue) and then combined to make a single object out of them. Note that the order in the list also determines which squares partially cover other squares, as the first one is on top, the second one is right below it, and so on. As seen in figure 3, to complete the pattern, the students created a small 4x4 blue square and placed it on top of the red one. Alternatively, to avoid the problem with the overlap, they could have constructed an L-shaped object and rotated it 4 times.

```
s7 = combined[painted(translated(rotated(solidRectangle(4,4), 45),
                                 (u62+0.1,-0.025)), "blue"),
              s71]
```

Figure 3: Pattern completion

Each team member created different objects and combined all objects to create the team's final quilt (See Figure 4). The final code is composed of 258 lines.

Figure 4: Unified Quilt

The students explained how their quilt represents their values, as follows:

> The values of generosity, respect, etc. contribute to the sense of unity which is what this quilt is all about. Every quilt comes together to make one single quilt that is better than any of them alone. This represents humans in a lot of ways.

Other students also represented various themes in their projects. For instance, 47.5% of the quilts represented the importance of family and friends in their lives, 21% represented life needs such as shelter, food and safety, 17% of the quilts represented the importance of freedom and peace, 12.5% represented southern culture, 8.75% represented students' homelands. Some quilts represented more than one aspect. 59% of the quilts are combined in harmony, each patch represents an aspect of the overall theme (See figure 5) and 41% are not combined in harmony

(See figure 4), each patch may not represent an aspect of an overall theme or the quilt lacks an overall theme.

In another quilt named “Black teens” students described their final quilt (See Figure 5) as:

> Morals, hobbies, and heritage are important because it makes up a person's beliefs and can decide the actions that they choose to take. K. made symbols about Kongo, S. made symbols about cotton, and I made symbols with music notes and paints.

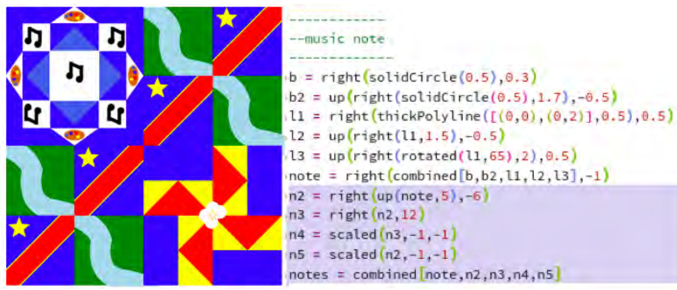

Figure 5: Black Teens Quilt

In the top-left patch in figure 5, a student built a note at the center and then made four copies at different corners. The code not highlighted shows how the student built a single note by combining circles and a segment [thickPolyline]. The highlighted code shows how the student translated the initial note to the two upper corners (n2 and n3), and then they used a reflection in each coordinate direction [scaled(...,-1,-1)] to get to the lower two notes (n4 and n5).

Results and Discussion

The results of this study suggest that students’ codes gave insights about how they used mathematics to design their quilt. The code gave detailed information about students’ mathematical strategies, which mathematical concepts they used correctly and the level of abstraction in their mathematical thinking. In addition, the computational medium gave students flexibility to devise multiple design plans using the power of mathematics (Barcelos et al., 2018) and opportunities to test their chosen approaches. The open-ended nature of the quilt task enabled students to engage in higher order thinking. To design their unique quilts, students had to figure out what procedures to use and why. This dynamic formative feedback had a potential to foster an understanding of the conceptual underpinnings of mathematical procedures (Guzdial & Shreiner 2021). In addition to synergies between mathematics and computation, this activity created a learning environment that was personally relevant to the students. As diSessa (2018) suggested “the freedom to take … ideas and put them to personal use [in this case expressing their values and beliefs tied to their cultural heritage]” (p. 14) makes the tasks personally relevant to the students and creates personal variations in the designed quilts.

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References

Alegre, F., Underwoood, J., Moreno, J. & Alegre, M. (2020). Introduction to Computational Thinking: A New High School Curriculum using CodeWorld. In *Proceedings of the 51st ACM Technical Symposium on Computer Science Education,* 992-998.

Barcelos, T. S., Muñoz-Soto, R., Villarroel, R., Merino, E., & Silveira, I. F. (2018). Mathematics Learning through Computational Thinking Activities: A Systematic Literature Review. *J. Univers. Comput. Sci.*, *24*(7), 815-845.

DiSessa, A. A. (2018). Computational literacy and "the big picture" concerning computers in mathematics education. *Mathematical thinking and learning*, *20*(1), 3-31.

Enyedy, N., & Mukhopadhyay, S. (2007). They don't show nothing I didn't know: Emergent tensions between culturally relevant pedagogy and mathematics pedagogy. *The Journal of the Learning Sciences*, *16*(2), 139-174.

Guzdial, M., & Shreiner, T. (2021). Integrating computing through task-specific programming for disciplinary relevance: Considerations and examples. *Computational Thinking in Compulsory Education: A Pedagogical Perspective,, Aman Yadav and Ulf Dalvad Berthelsen (Eds.). Routledge Taylor & Francis Group*.

Hickmott, D., Prieto-Rodriguez, E., & Holmes, K. (2018). A scoping review of studies on computational thinking in K–12 mathematics classrooms. *Digital Experiences in Mathematics Education*, *4*(1), 48-69.

Ladson-Billings, G. (1995). Toward a theory of culturally relevant pedagogy. *American educational research journal*, *32*(3), 465-491.

Li, Y., Schoenfeld, A. H., diSessa, A. A., Graesser, A. C., Benson, L. C., English, L. D., & Duschl, R. A. (2020). On computational thinking and STEM education. *Journal for STEM Education Research*, *3*(2), 147-166.

Schanzer, E., Fisler, K., Krishnamurthi, S., & Felleisen, M. (2015, February). Transferring skills at solving word problems from computing to algebra through Bootstrap. In *Proceedings of the 46th ACM Technical symposium on computer science education* (pp. 616-621).