From Professional Development to Pedagogy: An Examination of Computer Science Teachers' Culturally Responsive Instructional Practices

Introduction

A major challenge within the discipline of computer science (CS) is recruiting and retaining women and minoritized individuals to the field (Cuny, 2012). CS education at a young age can combat the representational gap (Tsan et al., 2016). While there are many explanations for the discrepancies in representation, the most pressing is a result of culturally irrelevant CS education (Scott & White, 2013). One way to contour teaching practices to engage diverse learners is through professional development (PD) that prepares teachers to integrate culturally responsive pedagogy (CRP) into curricula. CRP enables effective teaching, meaningful learning, and equitable learning environments (Gay, 2018; Ladson-Billings, 1995a). However, teachers' perceptions of their culturally responsive practices are often not aligned with their classroom instruction (Debnam et al., 2015). Self-reflection is an essential practice that requires educators to acknowledge their biases and positionality when attempting to integrate CRP into their teaching (Borrero et al., 2018). Only then can teachers authentically represent and harness students' cultural assets in their classrooms (Kohli, 2012). Our work seeks to address the underrepresentation of minoritized youth in CS by utilizing culturally responsive frameworks that integrate knowledge relevant to youth identities and communities with computational learning activities (Authors, 2019; Ladson-Billings, 1995b; Nieto, 2002). Specifically, we seek to answer two research questions:

1. How do teachers conceptualize CRP in the context of their own CS classrooms?
2. In what ways are teachers implementing culturally relevant tenets into their CS lesson plans after participating in a PD program focusing on the teaching of CS?

Culturally Responsive & Equity-Focused Framework

Our PD program incorporates a three-tiered approach to supporting teachers as they learn to integrate CS principles across K-12 curricula: (a) an annual week-long *Summer Institute*, (b) a college field experience course in which undergraduate student facilitators with background in CS assist teachers in implementing CS lessons back in their classrooms, and (c) sustainable partnerships with local schools. Our PD program has expanded to include a culturally responsive and equity-focused approach (see *Figure 1*), aimed at engaging teachers and undergraduate student facilitators in self-reflection and culturally responsive teaching strategies (Authors, 2019; Authors, 2020). During our 2019 Summer Institute, we focused on four CRP elements: promoting diversity, self-reflection, centering equity, and implementation (see *Table 1*). These elements were addressed through a series of activities adapted and implemented by the PD facilitators (authors) to introduce teachers to CRP and equity in CS (see *Table 2*). This paper focuses on how teachers processed and applied CRP and equity in their classrooms following their participation in the 2019 *Summer Institute*.

*** Figure 1, Tables 1 & 2 ***

Methods

Participants

A total of 25 teachers attended the 2019 *Summer Institute* (N=25). The Summer Institute is geared toward elementary and middle school teachers who are interested in integrating CS principles into their existing course materials. We used criterion sampling to select participants who worked in

schools that serve a racially and socioeconomically diverse population (n=9). Of these, six teachers completed all three elements of data collection for this study (see *Table* 3). Further, four of these teachers (n=4) previously attended our 2018 Summer Institute. Thus, they already had some background in both CS and CRP. In addition to core elementary teachers, participants taught business, technology, and library classes. Several participants also taught after school CS programming.

*** Table 3 ***

Data Collection

Qualitative data were collected from three different sources during the 2019-2020 school year: (a) interviews conducted at the end of the Summer Institute, (b) questionnaires administered at the end of the school year (June 2020), and (c) collection of lesson plans (*Figure 2*). Semi-structured individual interviews with teachers were conducted on the final day of the 2019 Summer Institute. Teachers were asked nine questions that targeted their experiences in the Institute, the effectiveness of the culturally responsive sessions, and ways to provide follow-up support. Four questions specific to the culturally responsive elements of our PD asked teachers to: (1) define CRP, (2) identify the connection between CRP and CS, (3) give an example of how students can use technology to solve real-world problems in their community, and (4) explain how they will apply what they learned about CRP to adapt their curriculum back in their schools. Four teachers attended the previous year's PD offerings (see Table 3). These four teachers answered three additional questions regarding their implementation efforts following their 2018 PD participation: (1) reason for attending multiple years, (2) applications of CRP in their classroom following the previous year's PD, and (3) the perceived impact of the second year of PD on their knowledge of CRP.

In spring 2020, due to restrictions in meeting with teachers, we administered an online questionnaire with seven questions via Qualtrics that asked teachers to self-report their use of CRP during the school year. Teachers were asked what it means to be a culturally responsive CS teacher, what support they may need to maximize their teaching success, and what culturally responsive teaching approaches they have used. Teachers were also asked how often they incorporated specific tenets of CRP in their CS classroom following their participation in PD. CRP tenets in relation to CS introduced in the PD included paired programming, creativity, student-led activities, and real-world problems. Following the questionnaire, teachers were asked to submit one of their culturally responsive lesson plans from the 2019-2020 school year.

*** Figure 2 ***

Data Analysis

Using an analytical approach inspired by grounded theory (Glaser & Strauss, 1967), interview and questionnaire data were analyzed to examine how teachers conceptualized CRP in relation to CS following their participation in PD. Data were coded based on three emergent themes: (1) pedagogical changes, (2) real-world application, and (3) broadening the scope of CS. Additionally, we developed a code book to examine culturally responsive elements in lesson plans which drew from rubrics developed by Weintrop et al. (2019), Aguilar-Valdez (2015), and Utah Valley University (see *Table* 4). Codes were grouped into two categories (equity and content/pedagogy) and applied during two rounds of coding by the researchers.

*** Table 4 ***

Results

Findings revealed that teachers understood and applied CRP to support CS instruction in different ways depending on the context of their classroom.

Conceptualizing CRP in the CS Classroom

Interview data revealed a number of CRP tenets teachers planned to incorporate into their teaching following their participation in PD. Teachers considered a variety of pedagogical changes to ensure student understanding: "You never know your class, the dynamics of the class, the population changes, behaviors, personalities. So I would say, specifically, modeling, restating, chunking, and then, some of the kids needed specific partners." (Cindy)

Although teachers became primarily interested in tools such as MicroBits (small hardware that can be programmed) and Scratch (object-oriented programming environment), they still considered the accessibility of resources for students inside school as noted by the following statement: " I'm definitely going to try and do some of the CS Unplugged activities. I don't currently have computers in my classroom, so any way to teach students different coding things and to teach them the importance of coding without having the computers is really cool." (Emma)

Further, teachers wanted to make an effort to connect community problems to their CS instruction. One example came from a teacher who was just introduced to BeeBots (programmable robots for young students): "We have problems in the world with recycling, so if I was to draw a maze out to where we would separate plastics and glasses and paper, the BeeBot could take those things to the recycle location." (Sandy)

Teachers also wanted to broaden the scope of CS to encourage student creativity. Ideas spanned across subject areas including music, cooking, and digital storytelling, as explained by Cindy: "I wanna work with the music teacher and find a way to kind of work together and collaborate using the Makey Makey Banana Keyboards. It's just about, you know, it's fun."

A variety of culturally relevant perspectives were reported in the follow up questionnaires as well. Emma, Deborah, Mary and Kathy believed that it was important to be aware of students' cultural identifications, backgrounds, and needs. Beth extended on that idea by discussing representation and equity: "I believe in order to be a culturally responsive CS teacher you must be able to teach in order to meet all of your students' learning needs in a cross-curricular or multicultural setting. We created a CS club at school where teachers encouraged students of all genders and ethnicities to join. I think it is also important as the teacher to keep in mind that all students come with different backgrounds and exposure to computer science activities."

Students' interests often guided lessons. Emma asked students for suggestions of topics they would like to cover. Kathy, Cindy, and Mary offered students "choice activities" like fashion design, game design, and coding a dance party. Most teachers reported using pair programming while teaching CS "about half the time". The majority of teachers reported they allow for student creativity "most of the time". Six teachers reported using real world problems in their computing lessons to varying extents and one responded with "never".

Integrating CRP into CS Lesson Plans

Lesson plans were analyzed for elements of equity (see *Table* 4). Cultural approaches were found in five lesson plans. Three lesson plans included aspects of meaningful and authentic identity and

computer science identity. Accommodations for student exceptionalities were found in three lesson plans. One lesson plan used a social justice dimension to teaching CS. Kathy, for instance, used non-CS topics to frame her lesson. She exposed students to world cultures and languages. She considered student's learning exceptionalities by using content with pictures, videos, and text with audio clips. Students produced computational projects in Scratch that represented their own cultures and heritage. Deborah engaged students through creative expression and contemporary youth culture. Students coded a dance party in Scratch using trendy dance moves and music in a variety of languages. She created a space that encouraged students to form their own CS identities by populating the classroom door with ideas about what CS means and why it matters to them.

All lesson plans had elements of content and pedagogy. Elements of CS specific content were found in every lesson. Every lesson also had responsive pedagogical practices. Elements of responsive instructional design and assessment practices were found in five lesson plans. Beth and Cindy, for example, created lesson plans for an after school club. They used CS content that aligned with appropriate standards and exposed students to relevant programming terminology. The lesson guided students through simple tutorials before progressing to harder tasks and open-ended activities that encourage experimentation. Using paired programming, students created race car games and presented their final product to the class.

Emma used different instructional approaches to engage students. She began with teacher-guided instruction to introduce students to the functions on a programmable mouse. Students were then assigned to group work. They created mazes and took turns trying to program the correct actions to navigate the mouse through the maze. Emma floated around the room to check for student understanding and encouraged problem solving and reasoning skills. Finally, she assessed students with an Exit Ticket that asked about their problem-solving skills.

Discussion & Significance
This research reported on the impact of a PD program on teachers' use of CRP in CS instruction. Teachers' demonstrated a strong foundational knowledge of what it means to be a culturally responsive educator and ways to create an equity focused learning environment. For teachers with repeated attendance, our PD established a lasting and influential impact on the way they use culturally appropriate instructional practices in their classrooms. Literature shows that shifts in such teaching practices can improve students' academic achievement and support an equitable learning environment (Bishop et al., 2009; Prater, 2014). Future research needs to follow teachers into their classrooms to observe changes in instructional implementation (Mellom et al., 2018). Importantly, research should continue to build on best practices for teacher PD that respond to contextualized approaches and application of CRP.

References
Aguilar-Valdez, J. (2015). *Rubric for culturally responsive lessons/assignments.* https://www.westminstercollege.edu/docs/default-source/undergraduate-documents/other-programs/tides/ rubric-for-culturally-responsive-lessons.pdf?sfvrsn=2

Alvarado, C., Dodds, Z., & Libeskind-Hadas, R. (2012). Increasing women's participation in computing at Harvey Mudd College. *ACM Inroads*, *3*(4), 55-64.

Bishop, R., Berryman, M., Cavanagh, T., & Teddy, L. (2009). Te Kotahitanga: Addressing educational disparities facing Māori students in New Zealand. *Teaching and Teacher Education, 25*, 734-742.

Borrero, N., Ziauddin, A., & Ahn, A. (2018). Teaching for change: New teachers' experiences

with and visions for culturally relevant pedagogy. *Critical QUestions in Education, 9*(1), 22-39.

Cuny, J. (2012). Transforming high school computing: A call to action. *ACM Inroads, 3*(2), 32-36.

Debnam, K. J., Pas, E. T., Bottiani, J., Cash, A. H., & Bradshaw, C. P. (2015). An examination of the association between observed and self-reported culturally proficient teaching practices. *Psychology in the Schools*, *52*, 533-548.

Gay, G. (2018). *Culturally responsive teaching: Theory, research, and practice*. Teachers College Press.

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Chicago: Aldine Publishing.

Gershenson, S., Holt, S. B., & Papageorge, N. W. (2016). Who believes in me? The effect of student-teacher demographic match on teacher expectations. *Economics of Education Review, 52,* 209-224.

Kohli, R. (2012). Racial pedagogy of the oppressed: Critical interracial dialogue for teachers of color. *Equity and Excellence in Education, 45*(1), 181-196.

Ladson-Billings, G. (1995a). But that's just good teaching! The case for culturally relevant pedagogy. *Theory into Practice, 34*(3), 159-165.

Ladson-Billings, G. (1995b). Toward a theory of culturally relevant pedagogy. *American Educational Research Journal, 32*(3), 465–491.

Mellom, P. J., Straubhaar, R., Balderas, C., Ariail, M., & Portes, P. R. (2018). "They come with nothing:" How professional development in a culturally responsive pedagogy shapes teacher attitudes towards Latino/a English language learners. *Teaching and Teacher Education 71*, 98-107.

Nieto, S. (1999). *The light in their eyes: Creating multicultural learning communities*. Teachers College Press.

Pollock, M. (2008). From shallow to deep: Toward a thorough cultural analysis of school achievement patterns. *Anthropology & Education Quarterly, 39*(4), 369-380.

Prater, M. A. (2009). Culturally responsive training of teacher educators. *Action in Teacher, 31*(3), 19-27.

Scott, K. A., Clark, K., Hayes, E., Mruczek, C., & Sheridan, K. (2010). Culturally relevant computing programs: Two examples to inform teacher professional development. In *Society for Information Technology & Teacher Education International Conference* (pp. 1269-1277). Association for the Advancement of Computing in Education (AACE).

Scott, K. A., & White, M. (2013). COMPUGIRLS' Standpoint: Culturally responsive computing and its effect on girls of color. *Urban Education*, *48*, 657–681.

Tatum, B. D. (2007). *Can we talk about race?: And other conversations in an era of school resegregation*. Beacon Press.

Tsan, J., Boyer, K. I., & Lynch, C. F. (2016). How early does the CS gender gap emerge? A study of collaborative problem solving in 5th grade computer science. Paper presented at the *SIGCSE 2016 - Proceedings of the 47th ACM Technical Symposium on Computing Science Education*, pp. 388-393. doi:10.1145/2839509.2844605

Utah Valley University. *Lesson plan assessment rubric*. https://www.uvu.edu/education/docs/accreditation/ida-scoring-rubric.pdf

Weintrop, D., Coenraad, M., Palmer, J., Franklin, D. (2019). The teacher accessibility, equity, and content (TEC) rubric for evaluating computing curricula. *ACM Transactions on*

Computing Education, 20(1), 1-30.

Acknowledgements

Figure 1
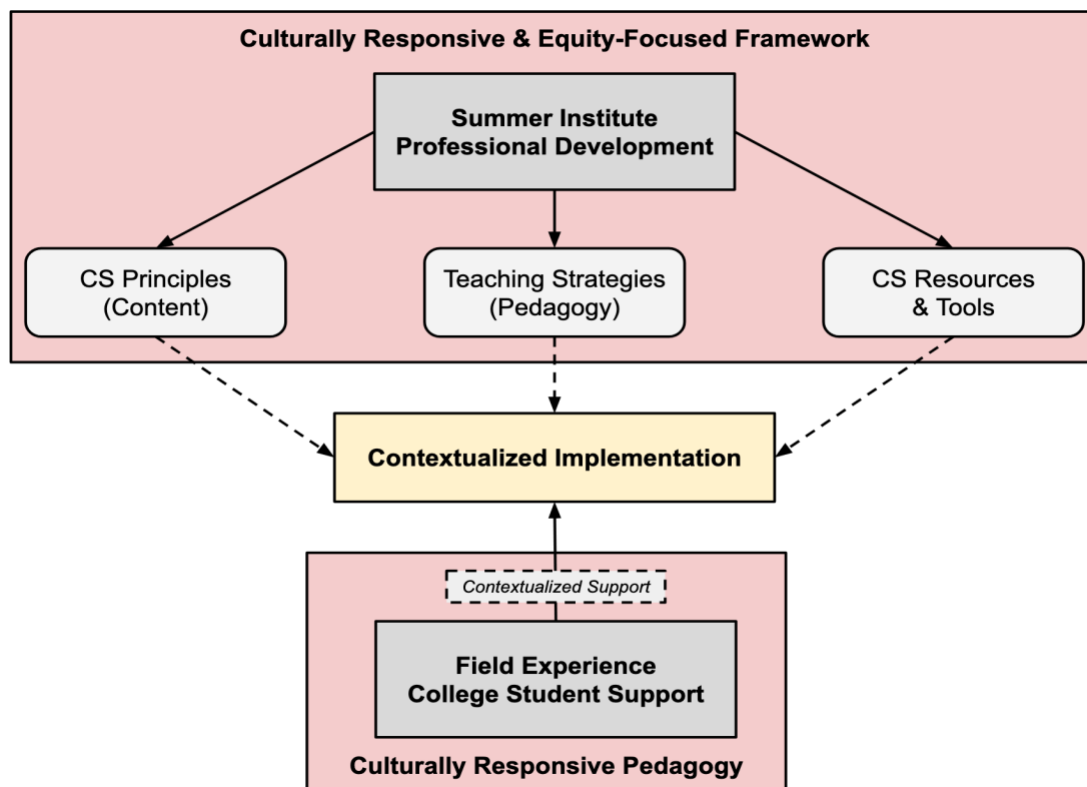*Culturally Responsive and Equity-Focused PD Model* (Authors, 2020)

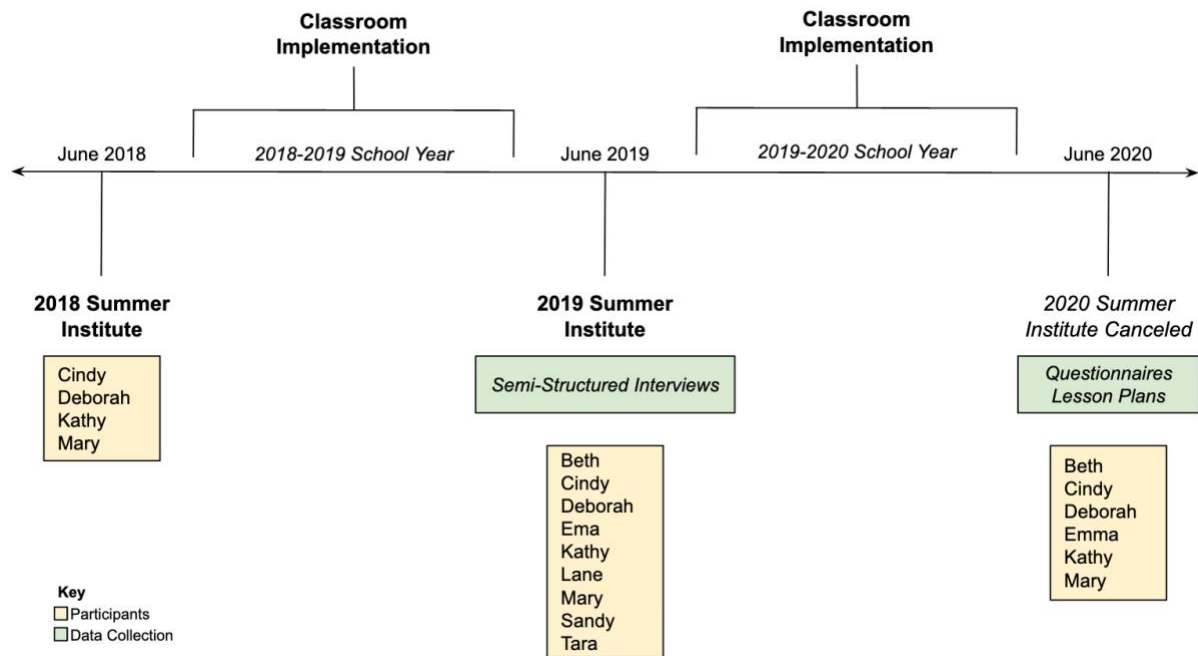**Figure 2**

Timeline of PD Activities and Data Collection

Table 1

Culturally Responsive and Equity-Focused PD Elements

Element	Purpose/Explanation	PD Activities	Literature
Promoting Diversity	Increasing participation in CS through equity-focused and research-based approaches Making CS relevant to solving real-world problems	"Identify, Recognize, Invite, Invite Together"	Alvarado et al., 2012
Self-Reflection	Defining CRP and reflecting on the impact of culture Thinking about ourselves and our students through a cultural lens Dispelling myths and confronting internal biases Identifying and avoiding microaggressions	Partner Walk Five Minute Poems Identity Wheel Identifying & Dispelling Myths Addressing Microaggression	Gay, 2018; Gershenson et al., 2016; Ladson-Billings, 1995b; Nieto, 1999; Tatum, 2007
Centering Equity	Adapting pedagogical approaches Centering culturally responsive interactions	Examples of CRP in CS Designing Robots to Save the World Exploring Shared Interests Assessing Creativity	Pollock, 2008; Scott et al, 2010
Implementation	Integrating CRP concepts into CS lesson plans Adapting existing curriculum to be culturally responsive	Peer feedback and support; individual and contextualized support	

Table 2

Description of CRP-related PD Activities

PD Activity	Description
Identify, Recognize, Invite, Invite Together	After helping teachers dispel common myths about why there are fewer female and BIPOC students in CS classes, they learned a four-step approach for improving the recruitment and retention of these minoritized students based on the successful recruitment and retention of female students in CS at Harvey Mudd College (Alvarado, et al., 2012). Teachers learn to identify promising students, recognize them for their abilities and achievements, invite them to take a CS class (or a more advanced CS class), and invite groups of students to sign up for CS classes together.
Partner Walk	Teachers engaged in self-reflection by telling personal stories. Pairs of teachers take a walk during which they take turns talking for three minutes straight about unique traditions from their family or culture. This activity was developed by Liz Brown at the University of Canterbury, who based this work in the Māori tradition of whānau or *extended family*.
Five Minute Poem	This activity was developed by Beverly Tatum (2007) to engage teachers in a written reflection on the community and culture that contextualized their childhood. The poem consists of four stanzas that each begin with the phrase "I am from." The first stanza contains the familiar sights, sounds, or smells from their neighborhood. The second stanza describes familiar foods they grew up eating. The third stanza shares family sayings and the fourth stanza describes specific people who influenced their life.
Social Identity Wheel	Teachers reflect on some of their social identities (race, gender, sex, (dis)ability, sexual orientation, etc.) and reflect on how these identities impact their self-perception or how they are perceived by others. For this activity, teachers complete the social identity wheel worksheet adapted for use by the Program on Intergroup Relations and the Spectrum Center, University of Michigan.
Addressing Microaggressions	Teachers were given examples of microaggressions female and BIPOC students may face in CS classrooms. Teachers worked in groups to practice identifying and addressing each scenario. This activity was adapted from the Computer Science Teaching Tips website (csteachingtips.org).
Designing Robots to Save the World	This activity asks teams of teachers to design a robot that would make the world a better place. The development of this world-changing robot relies on a combination of creativity, problem solving, and technological design as they work together to address real-world problems. This activity was originally designed by our team for middle school students in an after-school coding program.

Table 3
Participant Demographics

Pseudonym	Race	Gender	Experience (years)	Grade Level
Beth	White	F	9	Elementary
Cindy ▫	Asian	F	12	Elementary
Deborah ▫	Black	F	7	Middle School
Emma	White	F	6	Elementary
Kathy ▫	White	F	23	Middle School
Lane	White	F	26	Elementary
Mary ▫	White	F	22	Middle School
Sandy	White	F	8	Elementary
Tara	Black	F	11	Elementary

Note. All participants completed individual interviews following 2019 *Summer Institute.*
▫ Participated in 2018 Summer PD
  Completed 2020 Online Survey and Submitted 2019-2020 Lesson Plans

Table 4

Lesson Plan Rubric

Category	Code	Criteria
Equity	Culture	Incorporates the diverse cultures, perspectives, languages, and community values of students (cultural heritage and contemporary youth culture) Gives students the opportunity to share their own culture and cultural heritage Lesson incorporates real-life connections Connects learning to students' homes, neighborhoods, and communities
	Meaningful & Authentic Identity	Connects to students' interests without relying on stereotypes Opportunities for students to contribute their knowledge, perspectives, and experiences related to lesson topic Student identities represented in the curriculum and classroom materials Opportunities for students to represent themselves in their projects
	CS Identity	Creating a space that encourages a sense computer scientist identity
	Exceptionalities	Adapted for a variety of different types of learners (e.g. ELL, Special Ed) using alternatives, such as translations, pictures, and graphic organizers Extensions activities for students who meet the performance expectations Assessment methods are accessible and do not penalize for exceptionalities
	Social Justice	Connect learning to social, political, or environmental issues

Content & Pedagogy	CS Content	Coverage of the non-CS topics used as framing (e.*g.* historical events)
		Aligns with standards (e.g. K-12 CSTA Computer Science Standards)
		Content follows trajectory from less to more complex
		Integrates disciplinary terminology and promotes student usage
		Content tailored to student prior knowledge and skills within CS
	Pedagogical Practices	Students engage in computing skills and computational thinking
		Collaboration or peer-feedback
		Engaging and varied instructional approaches and learning strategies (e.g. discussions and student-centered *approaches*)
		Opportunities to share completed work with classmates and/or community
	Instructional Design	Incorporates prior knowledge unrelated to CS content (e.g. cooking, music)
		Questions promote higher order thinking (apply, analyze, evaluate)
		Scaffolding to promote understanding and independence (Use-Modify-Create)
		Opportunities to explore and provide solutions to open-ended questions
		Provides opportunities for students to reflect and express their learning
	Assessment	Objective-based assessments present throughout instruction
		Clear assessment criteria shared with students
		Students involved in self-assessment