# Incorporating Teacher Voice in the Development of Game-Based Learning Environments

**Abstract**

In this paper, we describe the DeCoAD process, which we used to co-design a game-based learning environment focused on computational thinking for middle grades students. We implemented the process with frequent, iterative collaboration with an Educator Advisory Panel informed by design-based implementation research (Confrey, 2019). The results of this co-design process demonstrate how we incorporated teachers' language and examples during game development. Our paper highlights the importance of incorporating teachers' voice during the development of technology-based learning games. Using a process similar to ours, researchers and teachers can co-design game-based learning environments to create stronger technology-based tools for stealth and immersive learning.

*Descriptors: Learning environments, situated learning, technology*

# Incorporating Teacher Voice in the Development of Game-Based Learning Environments

The pandemic pushed us to experience a new lifestyle. Technology was the primary tool to assist communication during this period and dramatically changed humans' work style, learning behavior, and problem solving. In school, Net Generation students (Net Gens) are more familiar with manipulating digital devices and multitasking than ever before. These students tend to be impatient in a linear teaching approach (Sharp, 2012). A challenge for educators and researchers is creating a more interactive learning environment to engage and motivate students.

## Computational Thinking

To tackle these challenges, researchers must understand the essential elements of manipulating digital devices. After Seymour Papert generated the term Computational Thinking (CT) in 1972, scholars devoted decades of research to this field. While most researchers focused on programming-based environments (e.g., Breanna & Resnick, 2012), Jeannette Wing's influential argument in 2006 broadened the scope of how CT is defined. Many scholars have acknowledged CT as an essential skill to live in the digitized world, which increasingly depends on computing competency (e.g., Cetin & Dubinsky, 2017). Jansen et al. (2018) concluded that CT could support people in organizing ill-structured issues into systematic problems and facilitate designing solutions that machines or humans can execute.

Grover and Pea (2017) further built a perspective that CT is a thought process like that which computer scientists use address problems. However, people who do not receive computer science training may not understand what it is to "think like computer scientists." Aho (2012) suggested viewing CT as the thought process related to formulating problems and solving them with computational steps and algorithms. In this study, we define CT as students' thought processes when confronted with problems that can be formulated into computational models to create solutions automatically executed by machines or replicated by humans.

## Game-Based Learning

Integrating computing into STEM and K-12 education is an urgent task for educators, researchers, and policymakers to assist students in adapting to the rapid-pace of growth in technology and jobs relevant to computing. Many tools are available for educators and researchers to teach CT in programming. However, coding is one small part of how computer scientists think, we need resources to teach students about CT more broadly. This study focuses on middle grades students exploring CT concepts in an online game-based learning environment. The game connects to current school curricula and assists teachers in teaching the most challenging concepts in the classrooms (Authors, 2020). Games are an excellent vehicle to motivate people's intrinsic interest in learning (Schifter, 2013). It also could provide authentic learning situations for students that trigger their enthusiasm in learning new knowledge (Sharp, 2012). Therefore, students will experience a unique learning opportunity, stealth learning (Sharp, 2012), and a state of flow through gameplay (Csikszentmihalyi et al., 2014), contributing to immersive learning in the gameplay world. One of the goals of our project is to extract learning assessment evidence during immersive gameplay on an existing mod *Lumberjack Tycoon* in Minecraft. The gameplay connects to Canvas Learning Management System for teachers to easily review students' work and assign new tasks. A custom, online planning tool for students provides enhanced learning opportunities to plan and check their work.

### *The DeCoAD Framework*

This study is part of a large interdisciplinary project focused on game development. Researchers and game designers created the **De**compose, **Co**nnection and **A**ctivity **D**esign (DeCoAD) process to help identify appropriate learning activities and embedded them in Minecraft (see Figure 1).

We implemented with DeCoAD process with frequent, iterative collaboration with Educator Advisory Panel (EAP). This paper will focus on the describing the co-design process, with was informed by design-based implementation research (Confrey, 2019). The primary research question for this paper is: *In what ways did we incorporate teachers' voice during the design of a game-based learning environment using the DeCoAD process? What did we learn from this collaboration?*

## Methods and Results

We employed an iterative, multi-step research design informed by design-based implementation research (Confrey, 2019; Fishman et al., 2007; Penuel et al., 2011). In this section, we will describe the methods and results for four steps which included identifying content standards, decomposing learning standards, connecting to game play, and designing the learning task. In collaboration with four local school districts, we identified six educators to serve on our EAP, which first met in March 2020. Three additional teachers were recruited to serve on the EAP in February 2021. EAP educators taught Grades 6-8 science, technology, computer science, or mathematics. Six educators identified as teachers, two identified as instructional coaches, and one identified as an instructional technology specialist. In the following subsections, we summarize the methods and results for each step of our research design and the accompanying results.

Outputs; Outcomes

### Determining Content Standards

**Methods.** Our first step focused on identifying content standards for focus in the Minecraft game. Initially, the inter-disciplinary leadership team comprised of two computer scientists, one of whom is also a game developer, and two learning scientists met to group the Grades 6-8 CSTA computer science content standards (CSTA, 2017), identifying: those that could be efficiently taught within Minecraft, those most relevant to CT, and those that were particularly important for students. We met with four EAP members in March 2020 to identify standards that were the highest priority, lowest priority, and most difficult to teach. We decided to focus the game components on 11 of 23 standards that were more difficult to teach, higher priority, could be integrated into Minecraft, were particularly important for CS and CT, and were important for students. We verified these standards with two EAP members in June 2020.

**Results.** In collaboration with the EAP, we selected 11 content standards to focus within the game. These standards were centered on four groups including: *Data and Analysis* (2-DA-07/ 08/09), *Problem Decomposition and Solution Design* (2-AP-10/13, 2-CS-03), *Organization and Teamwork* (2-AP-14/16/18), and *Equity and Impact* (2-IC-20/21).

**Decomposing the Content Standards**

**Methods.** We used an iterative process to develop content standard decomposition tables with three opportunities for educators to provide feedback. The process began with defining critical and relevant competencies related each standard. Next, two researchers separately reviewed curricular resources involved in CS and CT, which had been verified by other researchers and educators, to decompose targeted standards (*Data and Analysis*) into the tables.

We met with the EAP synchronously and asynchronously using tools like Jamboard. As shown in Figure 2, the sequence of doing EAP whole group meetings, one-on-one interviews, and virtual feedback via Jamboard constructed the iterative process.

**Results.** Educators' feedback showed that multiple factors influenced students' learning process. Researchers classified the essentials into three categories: language, learning activity design, and student ability.

- Language: Regarding educators' feedback, the number of statements for 2-DA-08 increased two-fold, and only received eight suggestions for 2-DA-07, none for 2-DA-09, because of time constraints. Most revisions and changes focused on clarification of language to make verbs more observable. Researchers found a gap of language between research field and classroom context. Teachers would utilize different terms or ways to teach and communicate with their students based on students' backgrounds.
- Learning activity design: Teachers suggested different examples that were more suitable to motivate students' engagement. Example preferences varied among educators teaching different subjects.
- Students' ability: Teachers wondered if students were well equipped with prerequisite competencies related to the learning standard and the game design provided sufficient instructions for students who had not played Minecraft previously.

## Connecting Content Standards to Game Elements

**Method.** Our next step was to construct a learning competency versus gameplay mechanic matrix to evaluate how the game decomposition addressed the learning standard decompositions. The matrix was revised to include new game mechanics afforded by the custom, online planning tool, which we included as a part of the gaming experience when we identified that additional technology-based tools would be necessary to address the learning standards as specified on the standard decomposition tables. The game mechanics were presented to the EAP via demonstrations, with virtual polls and comments captured. EAP comments were coded based on whether it supported, refuted, or was neutral towards a game mechanic.

**Results.** As a summary, when the panelists were asked about the overall appropriateness of the game mechanics for their grade level, four respondents rated them "Completely Appropriate," with one rating them "Somewhat Appropriate" due to concerns about students' familiarity with gaming on a keyboard or with Minecraft gameplay. Based on the feedback we received related to each gameplay mechanic mapped to the learning competencies including the custom, online planning tool, we felt comfortable moving forward with activity design.

## Developing Learning Activities

**Methods.** We drafted a learning task using gameplay mechanics informed by the feedback from educators. The 5Es instructional framework was utilized to integrate the learning competencies and game mechanics.

Three EAP members met with researchers in June 2021 to give their critical thoughts and feedback about 5Es instructional framework and what context could more relate to students' real life.

**Results.** The data from cognitive walkthroughs, game designers improved the text associated with non-playable characters and the content of learning assignments. Educators in EAP meeting agreed with 5Es was appropriate to design the learning activities. They had suggestions for making the overall task relevant for students.

1. Educators suggested that the tasks should be relevant to students' backgrounds. For example, the educators recommended connecting student learning to a problem that they could relate to, such as building shelters in Minecraft for families who were displaced by a natural disaster. Families in the area recently experienced losses due to a tornado.
2. Educators preferred to provide multiple story themes, tools, and materials to see how students make decisions and allow them to explain their choice.
3. The custom, online planning tool is a good way to encourage students to create a plan instead of skipping the planning phase. It also benefits teachers to check students' learning progress and provide them with feedback.

## Conclusion

This paper describes how we adapted an inherently educational game Minecraft to encourage students' development of CT skills. Designing games that are educational needs to combine the fun elements of games with learning that is motivational and interactive (Amory, 2007). This study utilized the DeCoAD process to design the gameplay experience, incorporating educators' feedback during game development. Through this process, researchers found that language used with the game is a critical factor that needs consideration and understanding when decomposing the content standards, creating gameplay surroundings, and designing learning activities. Without understanding the current interaction model in the classroom, the gameplay design may not receive the expected learning outcomes. Utilizing similar language and examples from teachers' instruction in gameplay can build a positive and familiar learning environment for students and enhance their motivation for new things. Therefore, the research design with the iterative process of incorporating educators' feedback is critical in connecting tightly with teachers' practical experience, benefiting designing learning activities to fit the real classroom situation better and boost students' learning performance.

**References**


Aho, A. V. (2012). Computation and computational thinking. *The Computer Journal, 55*(7), 832-835.

Amory, A. (2007). Game object model version II: A theoretical framework for educational game development. *Educational Technology Research and Development*, *55*(1), 51–77. https://doi.org/10.1007/s11423-006-9001-x

Breanna, K., & Resnick, M. (2012). *New frameworks for studying and assessing the development of computational thinking.* Paper presented at the American Educational Research Association, Vancouver, Canada.

Cetin, I., & Dubinsky, E. (2017). Reflective abstraction in computational thinking. *The Journal of Mathematical Behavior*, *47*, p. 70–80.

Confrey, J. (2019). Leading a design-based research team using agile methodologies to build learner-centered software. In K. R. Leatham (Ed.) *Designing, Conducting and Publishing Quality Research in Mathematics Education* (pp. 123-142). Springer.

Computer Science Teachers Association (CSTA). 2017. CSTA K12 Computer Science Standards, Revised 2017. Retrieved from http://www.csteachers.org/standards

Csikszentmihalyi, M., Abuhamdeh, S., & Nakamura, J. (2014). *Flow and the foundations of positive psychology.* Springer.

Fishman, B. J., Penuel, W. R., Allen, A., Cheng, B. H., & Sabelli, N. (2007). Design-based implementation research: An emerging model for transforming the relationship of research and practice. *National Society for the Study of Education, 112*(2), 136-156.

Grover, S., & Pea, R. (2017). Computational Thinking: A competency whose time has come. In S. Sentance, E. Barendsen, &S. Carsten (Eds.), *Computer Science Education: Perspectives on Teaching and Learning in School* (1st ed., pp. 19-38). Bloomsbury.

Jansen, M., Kohen-vacs, D., Otero, N., & Milrad, M. (2018, June). A complementary view for better understanding the term computational thinking. *Proceedings of the International Conference on Computational Thinking Education 2018*. Hong Kong: The Education University of Hong Kong.

Papert, S. (1972). Teaching children thinking. *Programming Learning and Educational Technology, 9*(5), 245-255.

Penuel, W. R., Fishman, B. J., Cheng, B. H., & Sabelli, N. (2011). Organizing research and development at the intersection of learning, implementation, and design. *Educational Researcher, 40*(1), 331-337.

Schifter, C. C. (2013). Games in learning, design, and motivation. In M. Murphy, S. Redding, & J. Twyman (Eds.), *Handbook on innovations in learning* (pp.149-164). Philadelphia, PA: Center on Innovations in

Learning, Temple University; Charlotte, NC: Information Age Publishing.

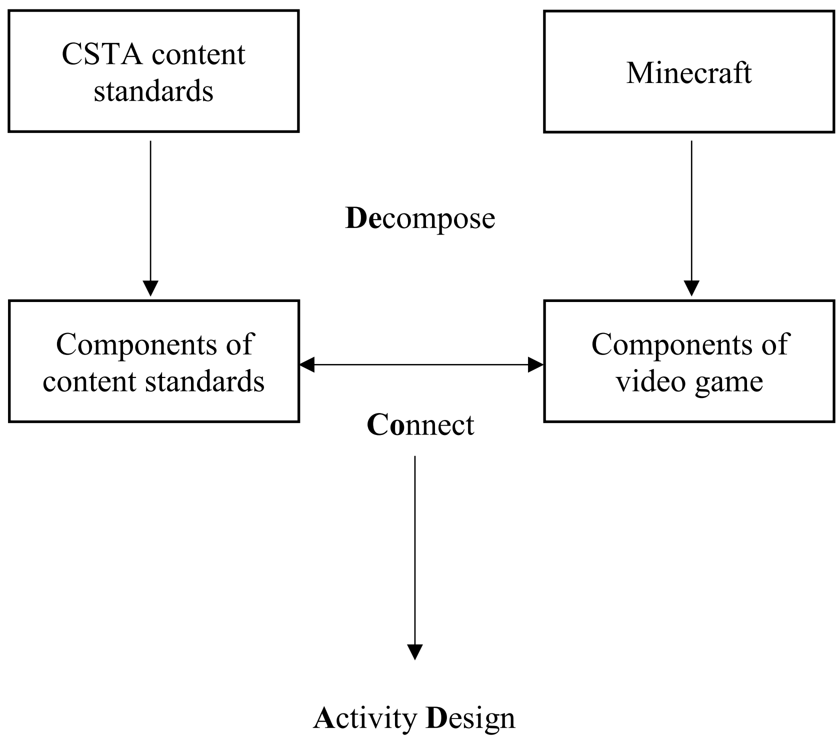
Sharp, L. A. (2012). Stealth learning: Unexpected learning opportunities through games. *Journal of Instructional Technology, 1,* 41-48.

Tseng, C. Y., Ketterlin-Geller, L. R., Clark, C. & Larson, E. (2020). *STEM+C educator advisory panel summer 2020* (20-18). Dallas, TX: Research in Mathematics Education, Southern Methodist University.

Wing, J. M. (2006). Computational thinking. *Communications of the ACM, 49*(3), 33-35.

Figure 1

*The DeCoAD Process*




*Note.* **Decomposition** is that Learning Scientists and game designers began to separately decompose select CSTA learning standards into standard decomposition tables and the game into a game decomposition document. **Connection** is that collaborators had to identify how to map the learning opportunities shown in the standard decomposition table into gameplay activities. **Activity design** is to utilize the instructional model to integrate the components of game and learning standards.

Figure 2

*The Iterative Multi-Step Design Integrating Educators' Feedback*

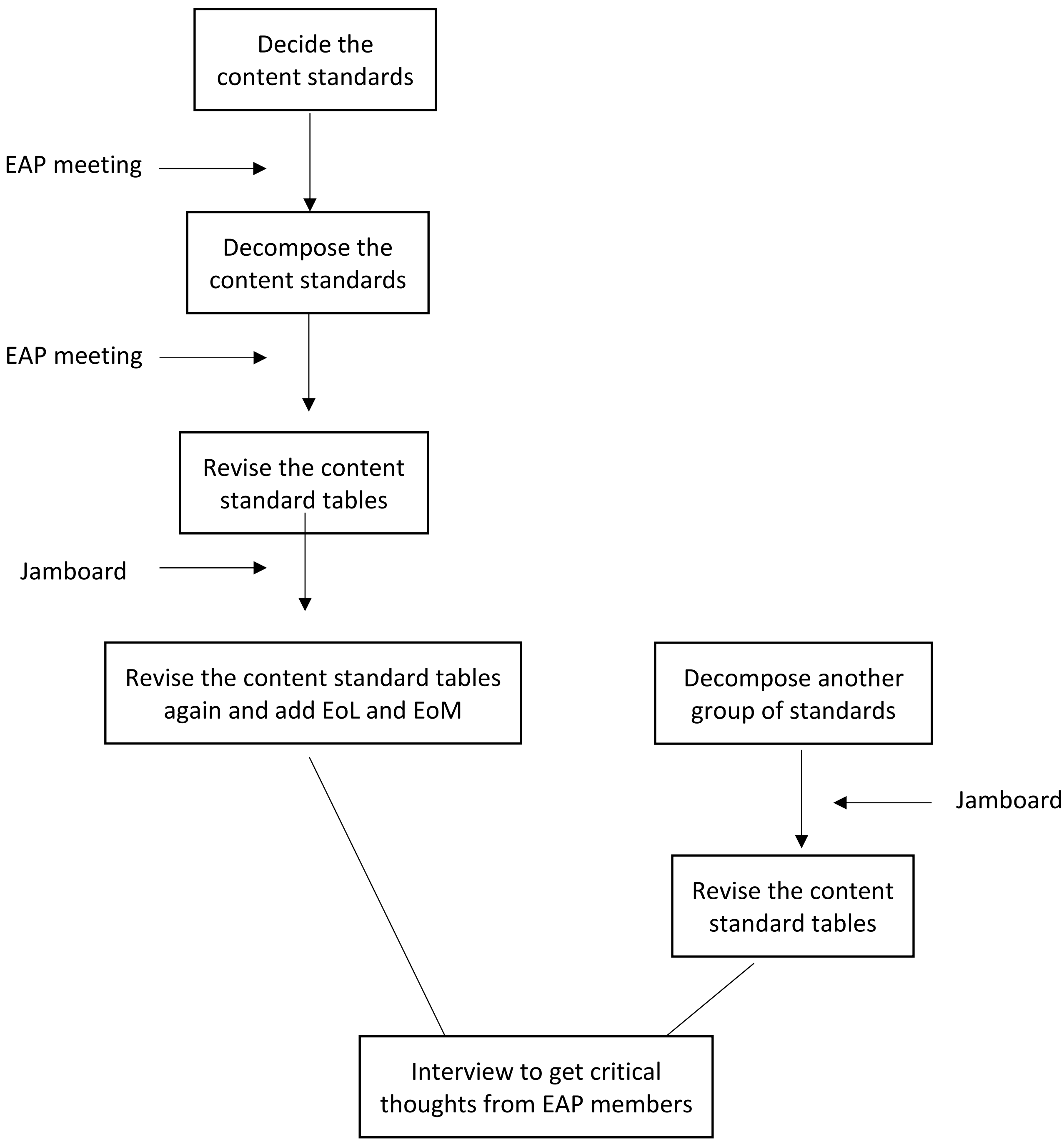
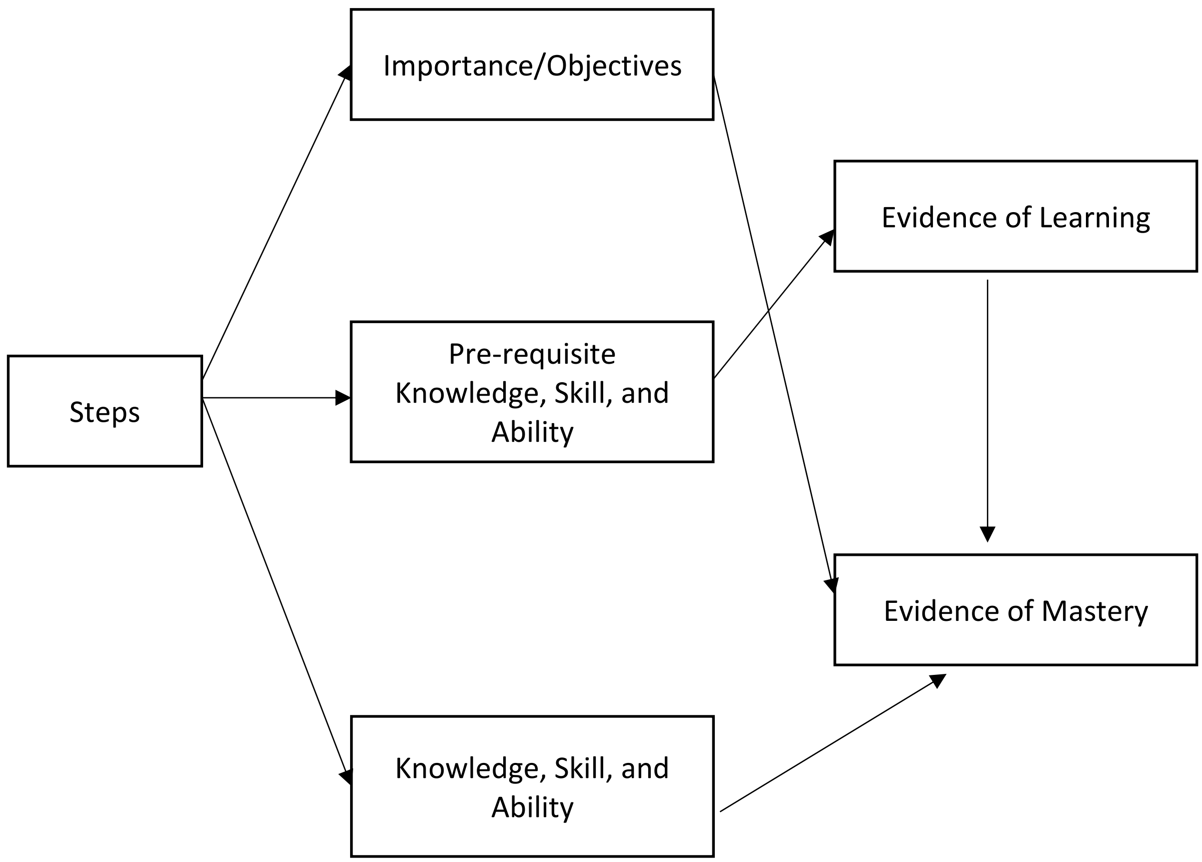


Figure 3

*The Relationship of Attributions in CSTA Content Standard Decomposition Table*




*Note.* Steps identify iterative steps within a standard, representing a sequence of cognitive behaviors related to the learning standard. Importance and Objectives (OIs) illustrate the importance of each step and the objectives that would be reached, and it is related to defining the evidence of mastery. Pre-knowledge, skill, and ability (pre-KSAs) require pre-requisite KSAs before learning the standard at each step. The Pre-KSA could be related to the evidence of learning and informed teachers what content knowledge students might need to review. Knowledge, skill and ability (KSAs) mean that students have the chance to learn at each step. The KSAs could be related to the evidence of mastery to inform teachers how to assess students' improvement possibly.