Interactive Assessment Tools for Computational Thinking in High School STEM Classrooms

David Weintrop, Elham Beheshti, Michael S. Horn, Kai Orton,
Laura Trouille, Kemi Jona, and Uri Wilensky

Northwestern University
2120 Campus Drive, Evanston, IL, USA, 60660
{dweintrop,beheshti}@u.northwestern.edu,
{michael-horn,k-orton,l-trouille,kjona,uri}@northwestern.edu

Abstract. This paper presents a pair of online, interactive assessments designed to measures students' computational thinking skills. The assessments are part of a larger project to bring computational thinking into high school STEM classrooms. Each assessment includes interactive tools that highlight the power of computation in the practice of scientific and mathematical inquiry. The computational tools used in our assessments enable students to analyze data with dynamic visualizations and explore concepts with computational models.

Keywords: Computational Thinking, Assessment, STEM.

1 Introduction

Computation is changing the way science and mathematics are practiced. The ability to use computational tools to carry out scientific inquiry is quickly becoming required in the modern scientific landscape. Despite this fact, high school math and science curricula have been slow to react to this trend. In response to this, the recently released Next Generation Sciences Standards (NGSS) includes "using mathematics and computational thinking" as one of eight core scientific practices [1]. As the number of states that adopt the NGSS grows, an increasing number of educators are faced with the challenge of figuring out how to bringing computational thinking (CT) into their classrooms. This includes defining what CT is in the context of a high school math or science classroom, designing curricula that teach CT, and developing assessments that accurately measure CT learning gains. In this paper we present our progress on that last challenge: the creation of authentic, interactive CT assessments.

2 Computational Thinking in STEM

The driving theme behind the computational thinking movement is the idea that knowledge and skills from the field of computer science have far reaching applications that everyone can benefit from. "[Computational thinking] represents a universally applicable attitude and skill set everyone, not just computer scientists,

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would be eager to learn and use" [2, p. 33]. This argument has been recurring over the last half century [3]–[5] and an large body of research has focused on issues of teaching and learning CT (or at least the skills associated with it) in schools [6]. The first step in our larger project of bring CT into high school STEM classrooms was the development of a skills taxonomy [7]. This taxonomy includes four high level categories: Data Skills, Modeling and Simulation Skills, Computational Problem Solving Skills, and Systems Thinking Skills. This taxonomy was used to inform both the assessments we designed and the classroom activities we developed.

Many computational environments and tools, as well as activities associated with CT, have been developed by researchers to promote CT competencies in K-12 STEM education. Directions pursued include the creation of simulation authoring tools such as NetLogo [8], and scaffolded computer-based frameworks that guide and support scientific inquiry like WISE [9]. This diverse set of CT tools, each of which are grounded in STEM concepts, informed our thinking about what CT assessments should include and the tools and interactions they should incorporate.

3 Assessing Computational Thinking in STEM

Two central design goals guided the creation of our assessment items. First, the assessment items must challenge students to apply the CT skills around which our activities focus. Second, the assessments should be authentic with respect to the types of questions asked as well as the nature of the tools the students use to answer them. Because of the computational nature of the subject area, it is critical that students engage with and use computational tools in order for us to have confidence that the assessment are achieving the desired goals of measuring computational thinking. Our assessments are hosted online as part of a custom-built assessment framework that gives us full control over all aspects of the look and feel each question and enables us to embed and customize the computational tools being used. Further, because we developed the framework, we can control the types and amount of data that are collecting for each student who takes an assessment[1].

3.1 Assessing Data Analysis Skills Using Motion Charts

The first assessment set we present is designed to measure students' mastery of skills from the data skills category of our CT in STEM taxonomy. These skills include: manipulating, analyzing, and visualizing data. The assessment has students investigate a dataset containing life expectancy, average income, and population for six countries over the span of 60 years. Using a Google Motion Chart (fig 1), students can view the data in three different formats (bar chart, line chart, bubble chart), choose the data to be rendered, and even 'run' the chart to see how values change over time. The questions ask students to both interpret and analyze the data provided as well as design visualizations to communicate a particular idea that the data support.

[1] The assessments can be found on the project's website: `http://ct-stem.northwestern.edu`

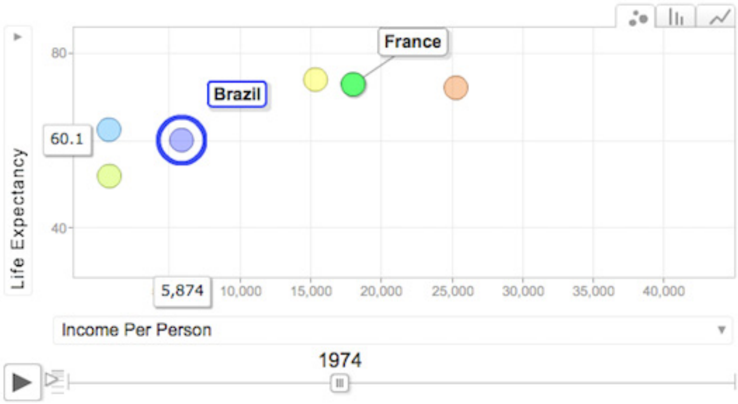

Fig. 1. The Google Motion Chart showing the relationship between life expectancy and income per person for six countries in 1974. This is one of three views provided by the Motion Chart.

3.2 Assessing Modeling and Simulations Skills with a Climate Change Model

The second assessment set we present has students interact with an agent-based model that allows students to investigate the underlying mechanisms behind climate change [10]. This model measures students' system thinking and modeling and simulation skills. The model is powered by NetLogo and allows users to configure the inputs that define features of the model (such as cloud coverage and the amount of CO_2 in the atmosphere). Unlike an animation, the model calculates the position and behavior of each element in the model as it runs, giving the student the ability to experiment with different settings to discover the cause of climate change. The model runs completely in the browser window allowing it to be embedded in the page alongside the questions being asked. Using this model, students answer questions that require them to run multiple trials and interpret the results, as well as, assess the overall validity of the model and identify assumptions build into the model and simplifications it makes.

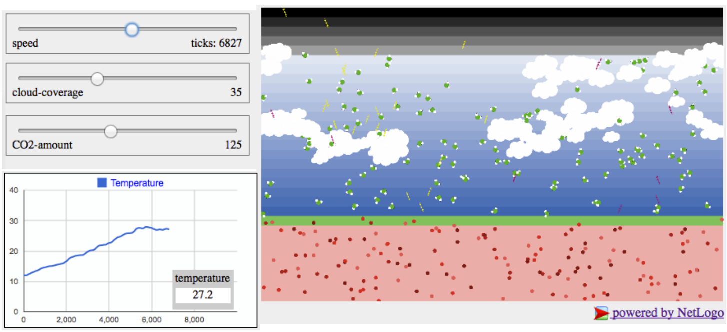

Fig. 2. The embedded NetLogo climate change model that student investigate as part of our assessment set measures students Modeling and simulation and systems thinking skills

4 Conclusion

In this paper we have briefly described the interactive components around which two sets of assessment items have been build that measures students' mastery of computational thinking skills within STEM disciplines. Unlike paper-based assessments, our online assessment sets have students use computational tools that let them explore and engage with the concepts in a dynamic way. This approach provides a more authentic form of assessment of CT skills as it situates the use of these skills within a computational context where they can be directly applied. Keeping pace with the increasingly computational nature of the concepts and practices central to the STEM fields is a major challenge facing classrooms today. Addressing this challenge requires not just new tools and classroom activities, but forms of assessment that can support and measure the computational ideas and practices that are central to CT.

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