Work in Progress: A Web-Based Tool to Assess Computational Thinking

Prof. Alka R. Harriger, Purdue University

Alka Harriger joined the faculty of the Computer and Information Technology Department (CIT) in 1982 and is currently a Professor of CIT. For the majority of that time, she taught software development courses. From 2008-2014, she led the NSF-ITEST funded SPIRIT (Surprising Possibilities Imagined and Realized through Information Technology) project. From 2013-2018, she co-led with Prof. Brad Harriger the NSF-ITEST funded TECHFIT (Teaching Engineering Concepts to Harness Future Innovators and Technologists) project. Since September 2016, she co-leads the NSF STEM+C project, Curriculum and Assessment Design to Study the Development of Motivation and Computational Thinking for Middle School Students across Three Learning Contexts, that builds on TECHFIT. Professor Harriger's current interests include outreach to K-12 to interest more students to pursue computing careers, applying IT skills to innovating fitness tools, and wearable computing.

Suyash Agrawal, Purdue University

Suyash Agrawal is currently pursuing M.S.(2019) in Computer Information Technology from Purdue University. He received his B.S.(2014) in Information Technology from JSSATE, Noida, India and then worked at Nokia as a software developer. His current research is focused towards Rapid Application Development.

Arjun Shakdher, Purdue University

Arjun Shakdher is currently a graduate student in the department of Computer and Information Technology at Purdue University. He has been working as a Graduate Research Assistant since 2017 on an NSF-funded program called TECHFIT, focused on Computational Thinking. His interest lies in Software Development, Cloud Engineering, Machine Learning, Network/Cyber Security, Analytics, Data Science and IT Project Management. He has previously worked as a Software Development Engineer at Ericsson and is an incoming Cloud Engineer at Amazon (2019).

Work-in-Progress:
A Web-Based Tool to Assess Computational Thinking

Abstract

When President Obama unveiled his plan to give all students in America the opportunity to learn computer science [1], discussions about Computational Thinking (CT) began in earnest in many organizations across a wide range of disciplines. However, Jeannette Wing stated the importance of CT for everyone a decade earlier in her landmark essay [2]. Since then, several people and organizations have posted their own definition of CT, which presents a challenge in being able to assess CT understanding and awareness in people. In an effort to build consensus on how to best assess CT, the authors have developed a web-based tool that will enable CT experts globally to populate, review and rate questions that address various attributes of CT.

TECHFIT (Teaching Engineering Concepts to Harness Future Innovators and Technologists) is an NSF-funded project that is examining the impact of their program's educational intervention based on the participants' delivery context. The CT tool was designed and developed as a functional, web-based tool that supports management of the CT questions database and gives different levels of access to various stakeholders, including the TECHFIT project team and academicians all over the world.

The CT tool includes features to enable authorized users to review, insert, and update a variety of questions in different formats. The level of access to this system is determined by the roles/ permissions granted by the administrator. It also enables users to have the ability to rate the questions. The ratings are then aggregated to yield an overall rating value. Attendees of the paper presentation will be invited to sign up and explore this tool to provide feedback for improvement of the tool.

Introduction

CT can be defined as "the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively implemented by an information-processing agent" [3]. Considerable work has been done by many people and groups to define and explain the importance of CT, but the numerous and varying definitions of CT cause confusion for prospective adopters of CT in K-12. Appropriate assessment is essential for CT to be included as part of the K-12 curriculum. Furthermore, being able to employ a web-based tool that is a repository of peer reviewed questions that could be used to assess CT skills in students should enhance the effectiveness of any curriculum incorporating CT [4]. Literature shows that a number of solutions have been developed but lack standardization, require prior programming knowledge, or are too lengthy [5] [6].

The tool described in this paper was designed to give users the ability to search for questions based on specific attributes. The questions can be rated by experts across the world for each attribute of CT. The aggregate rating is available to users for each question.

TECHFIT, an initiative to introduce and enhance CT abilities in young children, directly benefits from this CT tool. Teachers from over 40 schools across 11 states in the US have offered

TECHFIT as a class and/or an afterschool program. Students in the program create technology-supported fitness games, called exergames. Two programming tools are used in the curriculum. Nano Navigator is a flowchart programming tool that runs the associated microcontroller. Scratch is used to create animations that illustrate how the exergame innovations are played. Using both tools as well as engaging in physical computing through the construction of the physical systems are intended to help students develop and enhance their CT abilities. A future goal of this tool is to enable teachers to assess the CT skills of their students by using quizzes with questions from the tool's expert-reviewed database.

The ultimate vision of this tool is to house a large pool of questions spread across various dimensions of CT. This tool would act as a common medium for various academicians across the world who are interested in assessing the CT abilities of their students.

Background

Computational Thinking refers to thought processes that are involved when solving complex problems and generalizing and transferring this problem-solving process to a wide variety of problems [6]. It can also be defined as "the process of recognizing aspects of computation in the world that surrounds us and applying tools and techniques from Computer Science to understand and reason about both natural and artificial systems and processes" [7]. Zhong and Brennan [8] [9] describe computational thinking as having three key dimensions:

- Computational concepts which represent the concepts that designers employ as they program
- Computational practices which represent the practices that designers develop as they program
- Computational perspectives which represent the perspectives that designers form about the world around them and about themselves

One way of looking at CT would be as the habits of mind that are developed by designing, developing or debugging programs, software or just simple algorithmic chunks of code [10]. Thus, essential dimensions of CT may include attributes such as confidence in dealing with complexity, persistence in working with difficult problems, having a tolerance for ambiguity in dealing with open-ended problems, and the ability to work in collaborative groups towards a common goal [11]. Furthermore, Angeli [12] identifies the five computational thinking skills as Abstraction, Generalization, Decomposition, Algorithmic Thinking and Debugging.

It is evident that educators and researchers have difficulty in describing student's CT capabilities. Therefore, more and more researchers are highlighting the importance of student evaluation for pedagogical purpose [13]. Denning [10] identifies three basic questions that today's teachers and researchers struggle with:

1. What is CT?
2. How can it be assessed?
3. Is it good for everyone?

Brennan and Resnick [9] observe that CT has gotten considerable attention over the past decade. The definitions of CT vary depending on where they originate and as a result, there is little agreement about methods to assess the CT abilities of young people. One school of thought is that CT is a skill rather than a set of knowledge; therefore, it might be difficult to generate an accurate assessment tool that is not based on knowledge of facts but is rather evaluating skills that are abilities acquired over time with practice, knowledge and logical thinking [10].

A set of general suggestions for assessing the development of capacities for computational thinking include supporting further learning, incorporating artifacts, illuminating processes, checking in at multiple waypoints, valuing multiple ways of knowing and including multiple viewpoints [9]. Dr. Scratch is a tool that scores the student on the basis of CT skills while programming in Scratch [14]. The Fairy Assessment tool [5], used programming to measure and evaluate students but similar to Dr. Scratch, requires the overhead of learning programming.

Maintaining a standard set of questions (in the form of surveys, interviews or quizzes) that quickly produce consistent and reliable results can aid in the ability to assess the degree of CT skills. Thus, in order to evolve the approach to assess the computational concepts, habits and practices in an easy and effective manner, the proposed CT tool aims to provide teachers with a peer-reviewed question database where they can create, update, rate and delete questions catering to CT skills.

Introduction to the CT tool

The CT tool is a web-based platform developed for TECHFIT to support management of a standardized CT questions database. It is a responsive web application aimed at aiding various stakeholders, including the TECHFIT project team and academicians from all over the world. The tool includes features to enable authorized users to review, insert, and update questions in different formats. Using the concept of role-based access, the administrator determines the level of access for each user. Based on the role, a user may be able to view, modify or add questions to the database. The users may also have the ability to rate the questions with respect to their expertise regarding particular CT skills. Each question gets an aggregated rating for the same. This tool has been developed in such a manner that it can be used from anywhere in the world directly.

Role based access of the CT tool

The CT tool is accessible across the world by anyone with a registered username and password. The login screen is an important checkpoint to restrict unauthorized users from getting access to the questions (see figure 1).

The system also provides an option to sign up for new users. The new user can simply request login credentials by signing up for the tool by providing full name, role access level, a short bio, subject area expertise, position, name of employer, employer website, official email id and contact number. The information is verified by the administrator, and an appropriate role is granted to the user.

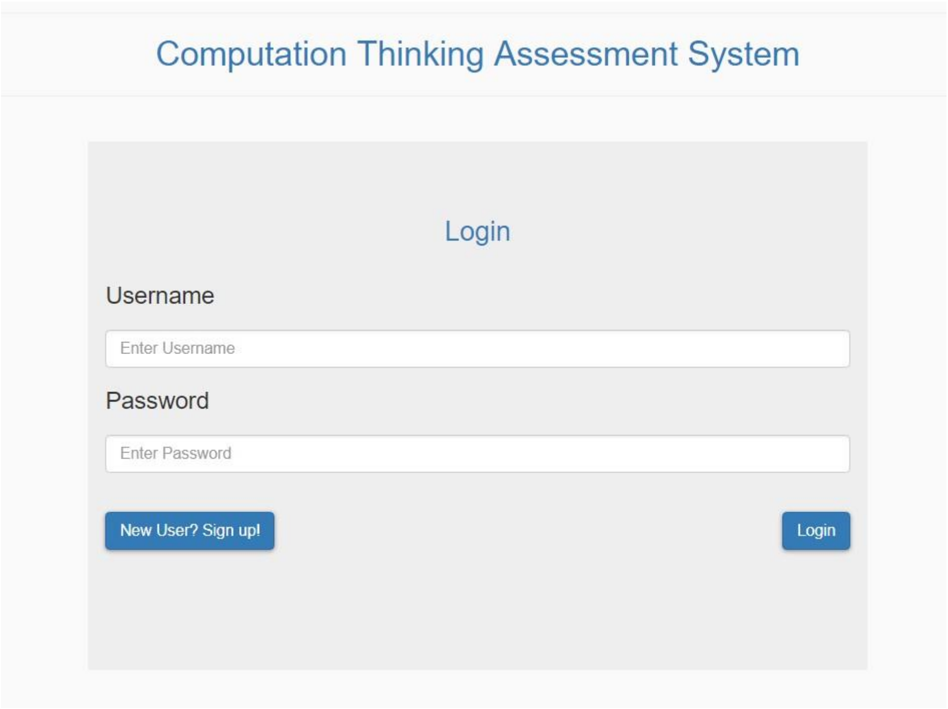


Figure 1: User Login Screen

The CT tool differentiates the access levels of users by providing different levels of access based on the role of the user. The following roles are available for new users:

- Administrator: The administrator has complete access to all the features in the CT tool. The administrator can add new users to the system as well as perform create, read, update and delete (CRUD) operations on various questions. The administrator can also modify habits, practices and concepts that are pre-populated in the system.
- Contributor: The contributor has limited access to the system. This role maps to academicians who would be interested in adding CT questions to the database. A contributor can add new questions and a base rating associated with the question as per his/her knowledge. This question is then available to be viewed and rated by other users. The contributor reserves the right to delete his/her question.
- Expert: The expert also has limited access to the system. This role maps to users with relevant Subject Area Expertise and provides them the capability to view and rate all questions in the CT database. This role is responsible for facilitating the rating of a question based on a specific concept or habit or practice.
- Viewer: The viewer exhibits the least amount of access to the system. This role simply allows the user to only view the questions available in the database without the ability to make any modifications. This role has been included in the system to allow new people to be able to view the collection of questions and still safeguard the system.

The role of a new user is decided by the administrator based on the information submitted by the user. The administrator also reserves the right to reject the request completely or ask for more information to determine the best role for that user.

Basic functionality of the CT tool

The design of the CT tool allows authorized users to perform Create, Read, Update, Delete (CRUD) operations on the question database. Once logged in, the user lands on a dashboard page that lists the various tiles selectable by the user. The user has two choices (see figure 2)

- View questions by selecting a concept, habit or practice in the top half of the screen.
- View questions by selecting a tile in the bottom half of the screen to see open ended, close ended or all questions.

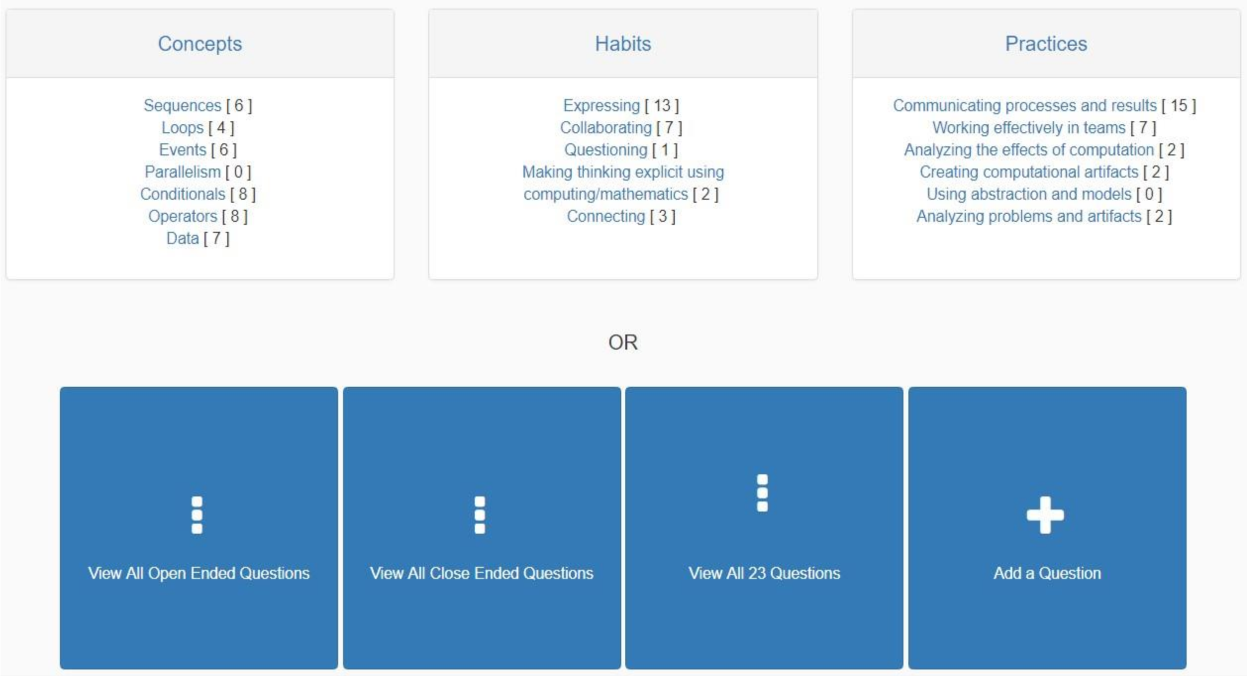
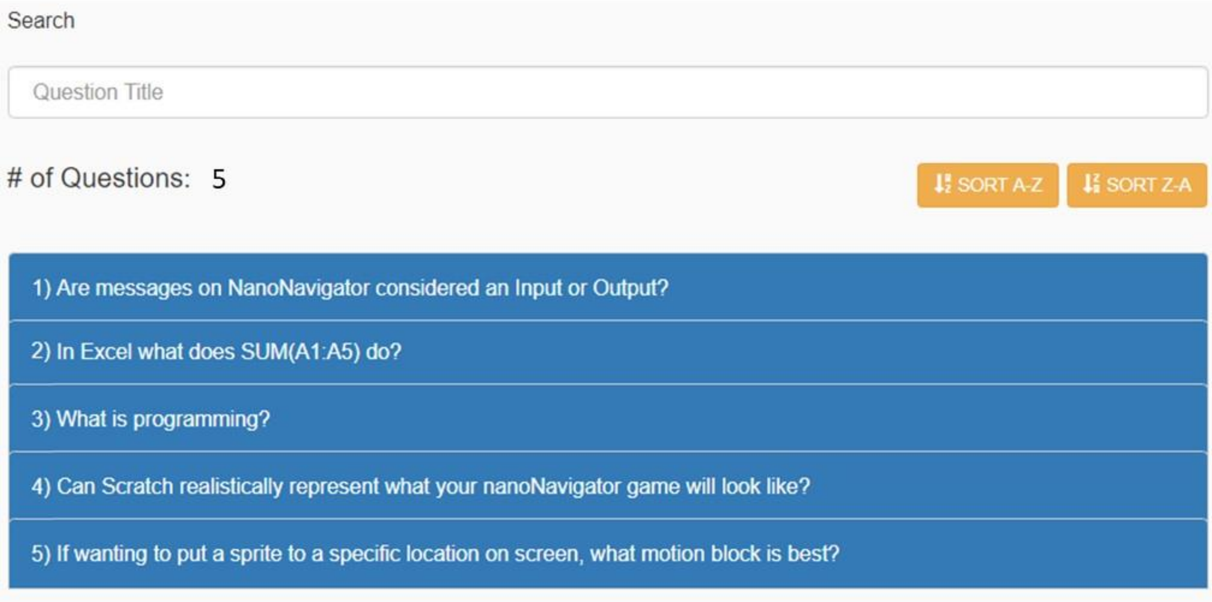

Concepts
Sequences [6]
Loops [4]
Events [6]
Parallelism [0]
Conditionals [8]
Operators [8]
Data [7]
Habits
Expressing [13]
Collaborating [7]
Questioning [1]
Making thinking explicit using computing/mathematics [2]
Connecting [3]
Practices
Communicating processes and results [15]
Working effectively in teams [7]
Analyzing the effects of computation [2]
Creating computational artifacts [2]
Using abstraction and models [0]
Analyzing problems and artifacts [2]
OR
View All Open Ended Questions
View All Close Ended Questions
View All 23 Questions
Add a Question

Figure 2: User Dashboard

Based on the selection made, the user gets redirected to the list of questions page. For instance, if the user selects Sequences under the Concepts tile, the page gets redirected to show all questions related to sequences that are available in the database (see figure 3). Because questions may be associated with multiple CT skills, they will appear when the associated skills are selected.

Though the list view only provides the question up front, the user can click on the question to see an expanded view of the question that includes the answer along with any notes, difficulty level, name of the contributor and source (see figure 4). The contributor name and source are shown to provide validity and authenticity of the source.

An important feature of the CT tool is that it provides the users with the ability to rate a question based on the alignment of that question with a particular concept, habit and/or practice. Authorized users can rate a question by assigning a value between 1 to 5, where 1 means very slightly aligned and 5 means strongly aligned. The user can rate multiple concepts, habits or practices (as shown in figure 5). The rating mechanism is transparent and unbiased as it allocates equal weights to all ratings irrespective of the level of the user. Thus, the aggregate rating for the question is the true average of all ratings related to that attribute.



# of Questions: 5

1) Are messages on NanoNavigator considered an Input or Output?

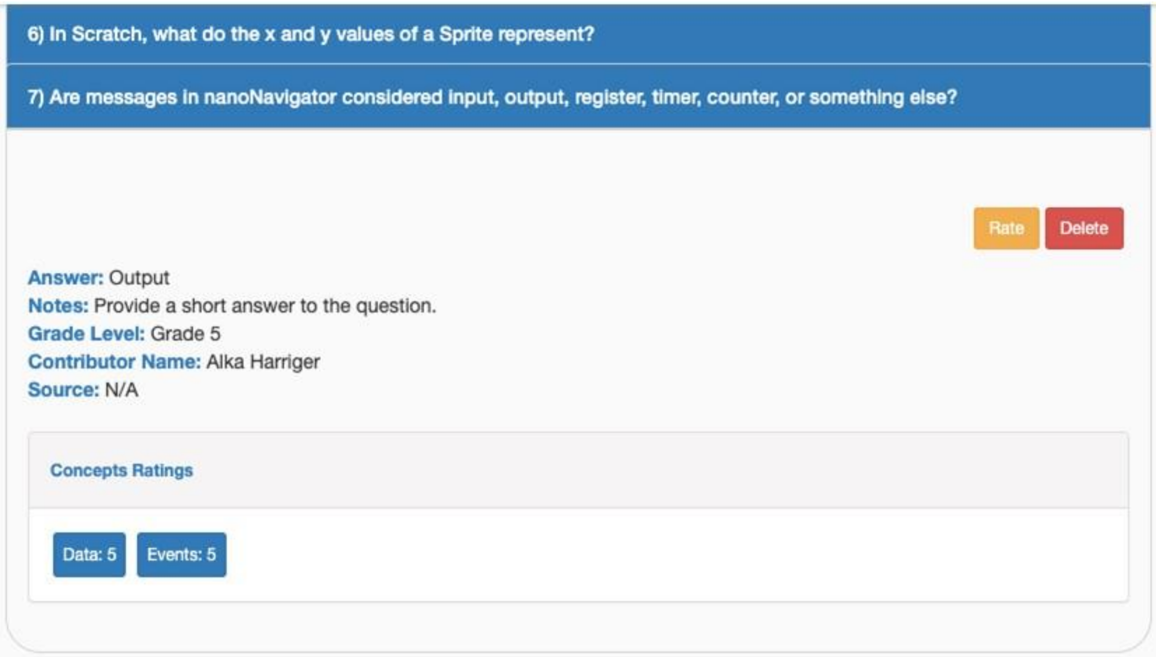
2) In Excel what does SUM(A1:A5) do?

3) What is programming?

4) Can Scratch realistically represent what your nanoNavigator game will look like?

5) If wanting to put a sprite to a specific location on screen, what motion block is best?

Figure 3: View Questions



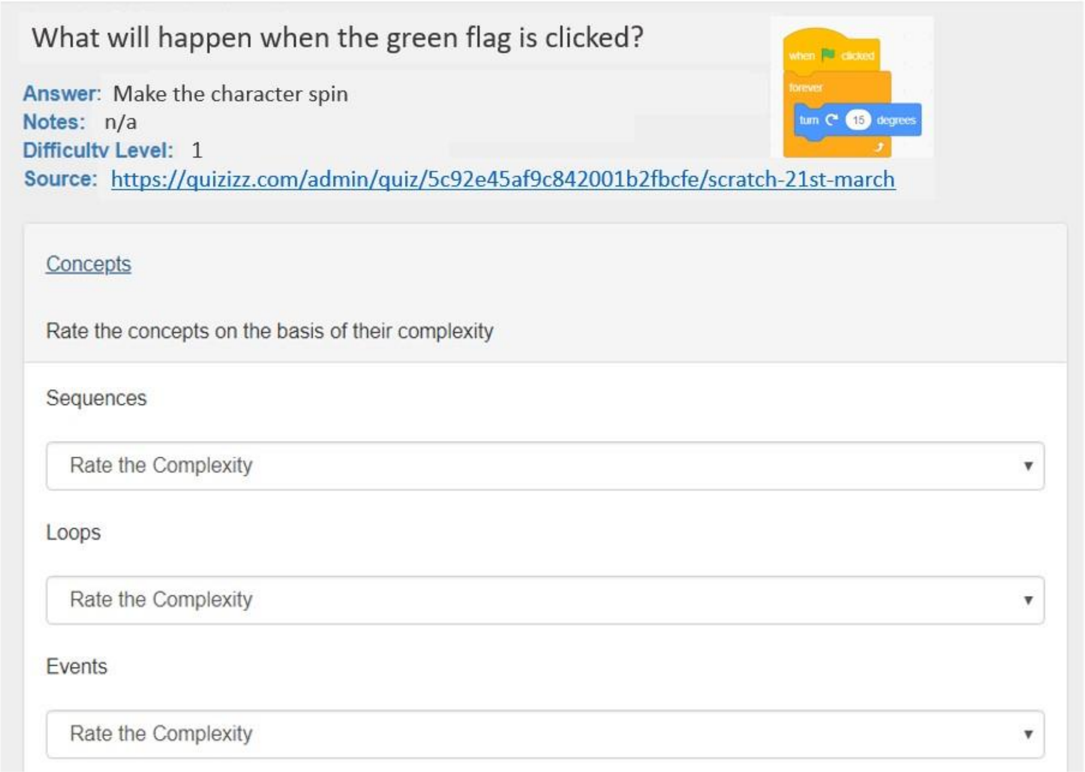
6) In Scratch, what do the x and y values of a Sprite represent?

7) Are messages in nanoNavigator considered input, output, register, timer, counter, or something else?

Answer: Output
Notes: Provide a short answer to the question.
Grade Level: Grade 5
Contributor Name: Alka Harriger
Source: N/A

Data: 5 Events: 5

Figure 4: Detailed View of Question



What will happen when the green flag is clicked?

Answer: Make the character spin
Notes: n/a
Difficulty Level: 1
Source: https://quizizz.com/admin/quiz/5c92e45af9c842001b2fbcfe/scratch-21st-march

Concepts

Rate the concepts on the basis of their complexity

Sequences

Rate the Complexity ▾

Loops

Rate the Complexity ▾

Events

Rate the Complexity ▾

Figure 5: Rating a Question

In order to facilitate the operation of the system, the current database has been pre-populated with several attributes documented in the literature and categorized as shown in table 1 [9].

Table 1: List of concepts, practices and habits populated in the database

Concepts	Practices	Habits
Sequences	Communicating processes and results	Expressing
Loops	Working effectively in teams	Collaborating
Events	Analyzing the effects of computation	Questioning
Parallelism	Creating computational artifacts	Connecting
Conditionals	Using abstraction and models	Making thinking explicit
Operators	Analyzing problems and artifacts	using computing/ mathematics
Data	Being Incremental and iterative Testing and debugging Reusing and remixing	

The CT tool is not limited to the above-mentioned attributes for habits, practices and concepts.

Users may submit a request to the administrator to modify or add a new concept, habit or practice. This feature exists to aid the possibility of getting new knowledge from experts as well as adapting to possible changes in expert views about CT. Thus, an expert can contact the administrator to request for a modification or addition of any skill. The final decision to approve or reject the request is at the administrator's discretion.

Conclusion

Computational thinking is considered a universal competency. Many groups are advocating for CT coverage to be added to every child's educational experience. While the literature shows many efforts to define CT, the methods for assessing CT are limited in number and time-consuming to implement. The proposed CT tool seeks to build a validated repository of CT-based questions that would be vetted and rated by subject matter experts. Deployed as a web application, it provides quick access to all users in a simple and easy to use interface anytime anywhere.

References

[1] White House. FACT SHEET: President Obama announces computer science for all initiative. Retrieved [4/20/17] from https://obamawhitehouse.archives.gov/the-press-office/2016/01/30/factsheet-president-obama-announces-computer-science-all-initiative, 2016.

[2] Jeannette M Wing. Computational thinking. *Communications of the ACM*, 49(3):33–35, 2006.

[3] Jan Cuny, Larry Snyder, and Jeannette M Wing. Demystifying computational thinking for non-computer scientists. *Unpublished manuscript in progress, referenced in http://www. cs. cmu. edu/˜ CompThink/resources/TheLinkWing. pdf*, 2010.

[4] Shuchi Grover and Roy Pea. Computational Thinking in K-12: A review of the state of the field. *Educational researcher*, 42(1):38–43, 2013.

[5] Linda Werner, Jill Denner, Shannon Campe, and Damon Chizuru Kawamoto. The fairy performance assessment: measuring computational thinking in middle school. In *Proceedings of the 43rd ACM technical symposium on Computer Science Education*, pages 215–220. ACM, 2012.

[6] Myint Swe Khine. Computational Thinking in the STEM Disciplines: Foundations and Research Highlights. Springer, 2018.

[7] Royal Society (Great Britain). Shut down or restart?: The way forward for computing in UK schools. Royal Society, 2012.

[8] Baichang Zhong, Qiyun Wang, Jie Chen, and Yi Li. An exploration of three-dimensional integrated assessment for computational thinking. *Journal of Educational Computing Research,* 53(4):562–590, 2016.

[9] Karen Brennan and Mitchel Resnick. New frameworks for studying and assessing the development of computational thinking. In *Proceedings of the 2012 annual meeting of the*

American Educational Research Association, Vancouver, Canada, volume 1, page 25, 2012.

[10] Peter J Denning. Remaining trouble spots with computational thinking. *Communications of the ACM*, 60(6): 33–39, 2017.

[11] Computer Science Teachers Association et al. Operational definition of computational thinking, 2016.

[12] Charoula Angeli, Joke Voogt, Andrew Fluck, Mary Webb, Margaret Cox, Joyce Malyn-Smith, and Jason Zagami. A K-6 computational thinking curriculum framework: Implications for teacher knowledge. *Journal of Educational Technology & Society*, 19(3), 2016.

[13] National Research Council et al. Report of a workshop on the pedagogical aspects of computational thinking. National Academies Press, 2011.

[14] Jesús Moreno-Leon, Gregorio Robles, and Marcos Román-González. Dr. Scratch: Automatic Analysis of Scratch Projects to Assess and Foster Computational Thinking. *RED. Revista de Educación a Distancia*, (46):1–23, 2015.