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ABSTRACT

Computational Thinking Bins are stand alone, individual boxes, each containing an activity for groups of students that teaches a computing concept. We have devised a system that has allowed us to create an initial set, test the set, continually improve and add to our set. We currently use these bins in outreach events for middle and high school students. As we have shared this resource with K-12 teachers, many have expressed an interest in acquiring their own set. In this paper we will share our experience throughout the process, introduce the bins, and explain how you can create your own set.

CCS CONCEPTS

• **Computer systems organization** → **Embedded systems**; *Redundancy*; Robotics; • **Networks** → Network reliability;

KEYWORDS

Computational Thinking, Outreach, Unplugged

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1 INTRODUCTION

Computational Thinking (CT) Bins were created in response to the many requests we received for outreach activities for middle and high school (secondary) students. Almost every week of the semester, some school would have a field trip to the University and we would be asked to “entertain” them for approximately an hour. Rather than just talk to them about our computing degrees, facilities, and research, we decided to actually *teach* them some computing concepts in addition to informing them about the school.

While we were familiar with CS Unplugged activities, we wanted something that required little to no explanation and that the students could do on their own. We wanted collaborative activities that could be completed in 10 to 15 minutes, or expanded for longer if needed. We based our model on the existing STEM Bins from our College of Education.



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Faculty in Computer Science and Teacher Education Development worked together to create a sample CT Bin and a template for all the required information we desired. We then developed a plan to allow the creation and testing of additional CT Bins. In this paper we report on our process.

2 BACKGROUND

There is a history in computer science education of utilizing computer-free “unplugged” activities which engage students in kinesthetic exercises that make computing concepts concrete. CS Unplugged [3], kinesthetic learning activities [2], and role plays in CS education [1] have been introduced at SIGCSE. In addition to use in primary and secondary computer science classrooms, these activities have been used extensively in out-of-school informal education settings such as camps, after-school clubs, and outreach. Most of these activities require a teacher or adult to lead the lesson, in order to provide instructions and guidance and to ensure that learning goals are met. For example, the “Card Flip Magic Trick”¹ requires a knowledgeable leader who can do the magic trick before explaining the underlying mathematics and computational connection to the audience.

Separately, at University of Nebraska Omaha, professors in the College of Education developed “STEM Bins.” Each STEM Bin is a stand-alone activity housed in a shoebox. In order to enable use in a wide variety of contexts, these STEM Bins were designed to be used independently by small groups of students without direct leadership or intervention by a teacher. Each bin contains all the instructions and materials to complete the activity, as well as an answer key if needed. Example STEM Bin activities include: “Geometric Models for Multiplication” in which colored popsicle sticks allow students to engage in inquiry about polynomials, “Building and Flying a Paper Boomerang,” and “Perspective Drawings” in which students create a three-dimensional shape with blocks and then create two-dimensional engineering drawings of different views of the shape.

The STEM bins have been useful in a broader range of settings than traditional outreach settings. They are useful for outreach in settings where participants vastly outnumber leaders, especially where participants are encouraged to move around freely, such as whole-school “STEM family nights” popular at local elementary schools and STEM celebrations at the university. They have also been used by teachers not only during formal instruction as hands-on activities, but also to provide independent extension activities for students who finish work early during class.

In the face of increased interest in outreach activities for CS Education Week and throughout the academic year, we were inspired to create computer-science themed “Computational Thinking (CT) Bins” beginning in the fall of 2016. Similar to the process described

¹<https://classic.csunplugged.org/error-detection/>

by Carroll in creating STEM kits [4], we determined that rather than creating all the bins ourselves, a professor of education would create a unique assessment opportunity by assigning bin creation in the computer science teaching methods course. Students experienced the existing STEM Bins as a model, then individually or in pairs created their own CT Bins according to the requirements of the assignment, as described in the following section.

3 ORIENTATION ASSIGNMENT

The assignment to create a CT Bin is given in the CS Teaching Methods course, as a summative assessment at the end of the semester. Students may work independently or in pairs, but each pair must complete two bins to receive full credit. The students are asked to utilize the knowledge they have gained in the teaching methods course to prepare an interactive, meaningful, collaborative instructional experience. It must teach a computing concept and be accessible for middle school or high school students with no prior computing experience.

3.1 Bin Authors

The students in the CS Teaching Methods course are pursuing an endorsement to teach computer science. Most of the students are enrolled as graduate students and are in-service teachers who are pursuing an additional teaching endorsement for computer science/information technology. Some of the students are undergraduate pre-service teachers who are pursuing multiple endorsements (computer science/information technology and at least one other). For the undergraduates, the CS Methods course occurs in their final semester before student teaching, and includes a practicum experience where they spend six weeks co-teaching in classrooms of their endorsement areas.

3.2 Bin Requirements

Students are given a template to complete in creating the bin so that the bins are standardized in their appearance. Because the bins are created for multiple purposes, they are required to have both Student Materials and Teacher Materials.

The student materials include a title, instructions written in age-appropriate, kid-friendly non-technical language, and any handouts, materials, etc. This may also include an answer key, if one is needed, which should be on a separate page so that it can be easily kept hidden while the students work through the activity. The instructions include a background section that gives a motivating introduction to the computing concept being covered. For example, a bin about computer art, in which students color in a picture encoded in hexadecimal, begins by briefly describing that the screen consists of dots called pixels which have a specific color, which are made up of differing amounts of red, green, and blue.

The teacher materials are designed to give the background and information a teacher would need both to use the bin and to understand its place in the curriculum. Each begins with an overview that describes the activity broadly. The recommended grade levels and estimated time the activity will take is included. There is also a recommendation for the ideal group size to work on the bin, and the number of groups the bin supports (e.g., students work in pairs, materials for 4 pairs). There is a connection to standards section

which identifies both the CSTA [5] and NE state standards that are addressed by the bin. There is a list of materials for the bin and any new vocabulary words with definitions that may be introduced in the CT Bin. A more complete description of how the activity should run and what students should do is also included. Finally, there is a “Connection to Computing” section which explains the underlying computer science concept(s). Because we assume that the teacher presenting the CT Bin may have little or no computing knowledge, a simple explanation of the purpose of the CT Bin and how it is related to computing is included. There is also a “Related Resources” section with links to more information. These last sections are particularly intended for substitute teachers or novice teachers who need more information to be able to support students in learning meaningfully from the activity. This information also helps a teacher use the bin as part of a larger topical unit, if desired.

Note that the teacher information is given to allow classroom teachers with no computing experience to use these and have the necessary information to answer questions or expand the activity if so desired. The activities do not require teachers to instruct or lead the students during the exploration process. The teacher information is provided to allow the teachers to also learn and discover the computing concepts along with their students and have the confidence to answer questions that may arise.

3.3 Assessment

The bins are assessed using a rubric, shown in Table 1. Student teachers receive feedback on how well their CT Bins meet the defined criteria. They are allowed to refine their CT Bins before the bins are then tested with outreach participants. Generally we invite those enrolled in the CS Methods course to participate in one outreach event during the semester (a STEM night, CS Ed Week event, or celebration of computing event) where they can see their CT Bins in action. This also serves as the initial testing of the CT Bin. Many teachers choose to update the CT Bin on their own after seeing it used by students.

3.4 Assignment Challenges

We have identified two major challenges with this CT Bins assignment in our CS teaching methods course: diversity of ideas, and originality of materials creation. These two challenges are connected—it is extremely difficult for teachers to create unique materials unlike those they have seen before. Teachers in our pre-service and in-service programs are exposed to a wide variety of materials, including those that are popular in national, breadth-first computing curricula like Exploring CS and CS Principles. Thus, the materials created were often similar to (or adaptations of) other materials available on the internet, such as CS Unplugged and NCWIT materials. In these cases, teachers adapted the existing instructions. The adaptations were for this independent context and elaborated on their connections to local standards. These bins typically scored quite well on the assessment rubric. However, when students did create unique materials for entirely new activities, the instructions were often less clear and robust compared to those adapted from professionally-developed and widely-tested materials. It was, therefore, a challenge to assess unique materials, since they were of lower quality than adapted materials but potentially were more

Table 1: Rubric for CT Bin Assignment

Criteria Topic	Target	Approaching Target	Below Target	Points
	The bin has a single purpose that is clearly communicated and straightforward to understand. The purpose or topic is strongly connected to computing. The bin topic is unique; there is not already a bin with this topic	The topic or purpose is unclear. There are multiple topics or purposes. There is a weak connection to computing. The bin is on a topic that is similar to other existing bins.	The topic or purpose is completely unclear. There is no connection to computing. The bin copies the activity of an existing bin	30
Usability	Students can complete the activity without oversight or instruction from a teacher. The activity is appropriately challenging for students of the identified grade level - not too childish nor too hard. The name is descriptive of the activity	Students can engage with the bin independently but may need teacher support to complete the activity. The bin is developmentally inappropriate for students of the identified grade level.	Students cannot reasonably complete the activity independently. The activity is likely to be impossibly difficult or so easy as to be boring for students of the identified grades.	50
Teacher Instructions	The teacher instructions are clear and complete. The computing concept(s) is/are fully explained for a novice teacher. The appropriate CSTA & state standards aligned with the activity are enumerated. There is a clear description of the working of the activity from a teacher point of view.	The teacher instructions are hard to follow. The concept is explained, but a novice teacher would find it challenging to understand the concept from the explanation. Some standards aligned with the activity are identified. There is a description of the activity, but it skips parts or is hard to follow.	The teacher instructions are missing or incoherent. The concept is not explained. Standards are not identified. There is no description of the activity.	20
Complete	There is a full materials list, license, authorship, and citation if needed.	The materials list is vague or incomplete. The license or authorship are missing. The activity appears to be a replication of another resource but no citation is given.	There is no materials list. The license and authorship are missing. There is evidence of intellectual property duplication from another resource. (Note: plagiarism is cause for failure and academic sanctions.)	10

creative and individualized than the adaptations. This remains an ongoing point of consideration in the design of this assessment task for our methods students.

Additionally, as we continue with this assignment, the current students now have access to the previously created bins. They are able to see what has been done before. Students have gravitated toward some particular bins, such as the cipher bins. It appears to be relatively simple to come up with a new cipher or encryption scheme and create a new bin. While we encourage students to be unique and creative in the assignment, many choose to take the easier path to completion.

4 CT BIN DESCRIPTIONS

As described above, all curated bins have a common look and feel and contain consistently structured details. Currently eleven different activities have been fully curated and are available for use, while an additional set of more recently submitted bins is still undergoing beta testing (see Section 5). Bins range in topics from searching/sorting algorithms to cryptography to image representation to computing history. Below, we briefly describe the nature of each presently available curated bin.

Robotic Buddies This activity engages students in basic notions of algorithms related to ordering and specificity. Students must use a restricted symbol language to instruct their partner how to “play robot” and assemble a given configuration of cups (see Figure 1a).

Beat the Clock Inspired by classic game shows, students are challenged with guessing the price of everyday items at various price points (e.g., a can of RedBull, a Bluetooth speaker) while counting the number of guesses needed. They consider different strategies to arrive quickest at the answer and in so doing discover binary search.

Computer Art Introduced earlier, this bin presents students with grids of decimal and hexadecimal numbers which students must identify as RGB colors. They then are asked to fill in the square regions (i.e., pixels) using colored pencils to discover the image being represented (see Figure 1b).

Card Sort In this bin, students find envelopes containing a single suit of playing cards along with some straws and English descriptions of various sorting algorithms (insertion, bubble, and merge). The goal is to explore each process and consider how they are similar or different (see Figure 1c).

Data Storage Timeline Here students explore the history of consumer data storage devices by trying to line up actual devices from oldest to newest based on their timeline of introduction to the marketplace. They also try to match description cards to the corresponding device (see Figure 2a).

Enigma Machine This bin contains a pair of “crisp tube Enigma machines”² along with some basic instructions about Enigma’s history and how the tubes work. A series of both easy (single rotor) and hard (multi rotor) messages challenge students to practice their decoding skills and explore Enigma’s complexity (see Figure 2b).

Balance it Out This activity challenges students to invent a comparison sorting algorithm and write it down as a sequence of steps. A classroom balance and a series of variably weighted containers is provided (see Figure 2c) for students to practice their steps while reinforcing that only one comparison can be made at a time.

Caesar Cipher Shown in Figure 3a, this activity allows students to practice encoding and decoding message written using a simple alphabetic shift substitution cipher.

²http://wiki.franklinheath.co.uk/index.php/Enigma/Paper_Enigma

Scytale Cipher For this activity, students are given a series of paper strips containing messages that can be decoded when wrapped around the correct diameter wooden dowel (see Figure 3c). They learn the history of the Scytale Cipher and are tasked with encoding their own messages.

Computers Thru History Like the data storage activity, this bin explores computing history (see Figure 4a). Students are given cards containing photos of significant computational devices ranging from an abacus to the Hollerith machine to the ENIAC. The challenge is to arrange them in chronological order and match them to descriptions of each.

Vigenère Cipher This two dimensional cipher challenge introduces students to the Vigenère square (see Figure 4c) and asks them to decode messages using different keywords. The bin also explores the relationship to Caesar Cipher in the event that students have completed multiple activities.

5 TESTING AND REFINEMENT

Following the conclusion of the CS teaching methods course, the newly created set of bins is pilot tested with students and teachers in a wide variety of contexts at our university. These events range from campus-wide STEM open houses, summer camps sessions, teacher PD workshops, to current classes. The primary goal of these pilot tests is to collect feedback about the clarity of the instructions in the bin, while also informally gauging the length of time learners take to successfully complete the activity. Every bin is pilot tested at least twice before being included into the final vetted set of bins.

Feedback cards are placed in each of the bins so that learners can report any difficulties with the activity or errors in the instructions, instructional materials, or answer keys. This feedback is then used to refine the original content of the student-created CT bin. If a major update to the materials or instructions is required, the bin undergoes another round of pilot testing. Once a bin receives positive feedback with minimal errors, the errors are corrected and the bin is promoted into a curated version. The curated version is once again reviewed by our university faculty. The supporting documentation is produced and the bin is then added to our publicly available list of bins.

5.0.1 Supporting Materials. Once the bins have been tested and refined, the documentation created in the assignments is transferred into a LaTeX template. We have utilized high school interns and undergraduate students to help in this process. Faculty review the standards mapping and the content describing the activity's relationship to computing. Curators also check to ensure that the material is not plagiarized from another source. Because all the CT Bins are licensed under Creative Commons, we only use material that can be freely used with attribution and allows derivation. All the documentation for the student, teacher, answer keys, and any reproducible materials (such as pictures, diagrams, codes, etc.) are bundled together into a single PDF document.

In addition to the individual instructions for each bin, we also maintain a *purchase list* that contains a supply list for creating an entire set of CT Bins. The contents of all the bins are included in a spreadsheet and tallied across all bins. For example, many bins require extra paper and pencils. A complete count of the number of pencils and pads of paper (or small stacks) is given with a mapping

to all the bins that require that supply. By having an entire purchase list available, any teacher that wished to make an entire set or large subset of CT Bins would have a single supply list.

We also supply designed labels which can be printed and placed on the bins to help identify them. The files containing the labels are additionally updated and made available.

6 BOX PREPARATION

Preparing a set of CT Bins from the curated materials is a fairly straightforward process. After procuring the needed items from the purchase list and the desired containers, the bins can be assembled. All of the PDF files should be printed. Copies of student materials need to be made along with copies of the necessary instructional materials. The purchase list indicates which bins require copies and exactly what must be copied. Once these copies have been made, the first step is to separate the student instructions, the answer key, and the teacher materials into separate, clearly labeled folders and envelopes as shown in Figure 3a. Some materials, like the cipher wheel or the storage device description cards shown in Figure 2a, can be laminated to increase their durability over time. Lamination can also enable use of a dry-erase marker for repeated student use without restocking the bin with additional photocopies. This is often helpful with the cryptography related bins.

Some bins require assembly of the instructional material. Instructions for assembly, often accompanied by links to YouTube videos, are provided. For example, we have provided links to Thinkiverse sites with files for 3D printing Caesar cipher wheels (see Figure 3b). We also provide links to YouTube videos for constructing the Enigma machine.

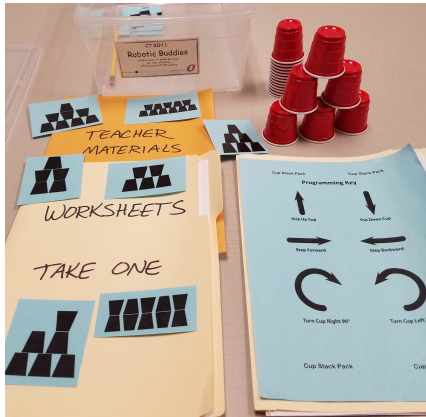
Once these materials are prepared, assembly of the box is a simple matter of placing the folders into the bin along with copies of any handouts and/or special materials for the activity, like the scale and bottles in Figure 2c. Any such needed materials are described in the teacher materials for the associated bin. The folder containing teacher materials can optionally be included at the bottom of the bin, or simply excluded to avoid any potential for confusion by the students completing the activity. Finally, the labels for the bins should be printed and attached to each bin.

7 AVAILABILITY

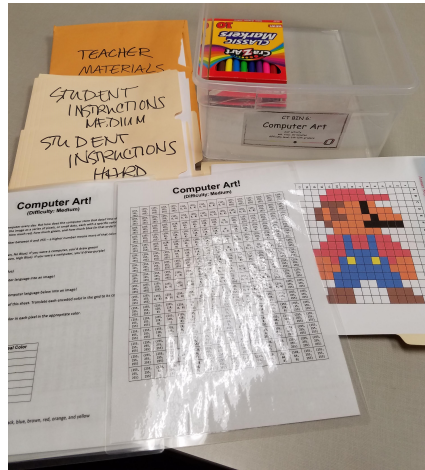
We have made all of the information related to our CT Bins publicly available through a Creative Commons license. All the information needed to create your own set, including a purchase list, labels, and the instructional materials can be found at <https://bit.ly/UNOCSED>. Scroll down to the Unplugged Materials and select the Computational Thinking Bins link. A link to a zipped file containing all the materials needed can be found on the resulting page.

8 USAGE

We currently have multiple sets of the CT Bins which we continue to use for outreach activities. Additionally, we have added the bins to our "lending library". Local area teachers may complete a request form on the internet to borrow one, two, or up to an entire set of CT Bins for a period of one week. We arrange a time for pick up and we have the requested bins ready for transport. When the bins are returned, a high school intern or undergraduate student worker



(a) Robotic Buddies

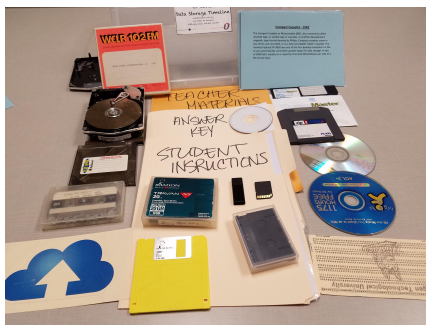


(b) Computer Art

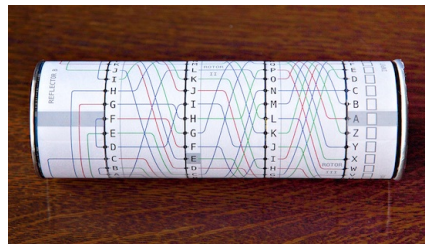


(c) Card Sort

Figure 1: First 3 CT Bins



(a) Data Storage Timeline

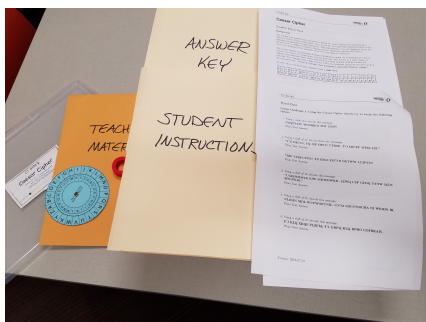


(b) Enigma Machine



(c) Balance It Out

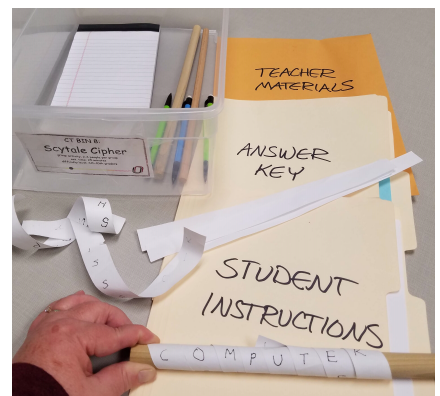
Figure 2: 3 More CT Bins



(a) Caesar Cipher



(b) 3D Cipher



(c) Scytale Cipher

Figure 3: Cryptography CT Bins

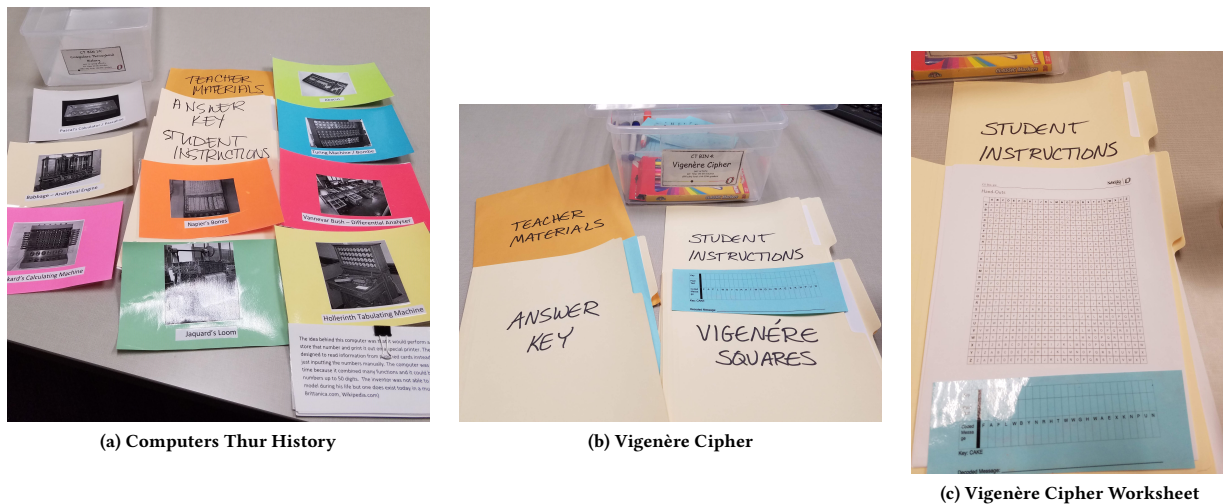


Figure 4: Final 3 CT Bins

to restock the bins and ensures that all materials are included in the returned bins. This is also when we resupply any necessary instructions, worksheets, or other consumables.

In addition to our lending library, thanks to a Google grant, we have been able to create sets of the bins for use by our Educational Service Units (ESUs). ESUs serve as intermediate level education service agencies for member school districts. There are currently 17 ESUs providing services to 261 public school districts in Nebraska. ESUs provide core services for school districts, which include staff development, technology, and instructional materials. x

Through the Google grant, we created sets of CT Bins for several ESUs and held a Professional Development session at the ESU. Teachers from the school districts served by the ESU were invited to attend along with up to five students for a day of learning about computing. The students and teachers experienced the CT Bins together. The bins were placed on tables and the students were allowed to choose which bin to work on. After 15 minutes, students were encouraged to move to a different bin. After 90 minutes, the students were asked to gather and listen to the explanations behind each of the bins along with their connections to computing. After student exploration, the researchers lead a discussion with the students on what they had learned. Students were able to define and explain algorithms, explain the concept of cryptography, and discuss computing storage devices. Additional educational resources were presented for students who wanted to continue to explore a specific topic. The goal of the CT Bins is to allow for student engagement with computing concepts without the need for an instructor or lead. While we certainly expected that students would learn while engaged with the bins, we were not explicitly trying to achieve deep learning of computing concepts, merely an introduction to spark additional interest. The CT Bins certainly met this goal. A set of CT Bins created specifically for each ESU was left there for further outreach activities after the Professional Development Day.

The CT Bins were also presented at the 2018 CSTA National Convention to over 300 attendees. Attendees were allowed to “play” with the bins and examine their contents, and some even completed the activities. The attendees were provided business cards with a URL to access a zip file containing all the materials for creating their own sets of CT Bins. The comments received from the attendees expressed their appreciation for the materials and how many were looking forward to using the bins in their classrooms. Many expressed interest in having their library obtain a set for maximum exposure. Many teachers wanted a set for use when students finished their assigned work early, as an extension activity. Other expressed interest in having a set for substitutes to be able to use during the year.

9 CONCLUSIONS

In this paper we presented the guiding philosophy and design of Computational Thinking Bins. These self-guided activities are unique from other existing curricular resources in that they enable individual and small group interaction within a self-contained activity that requires little-to-no teacher preparation.

Not only have the CT Bins described here been a well-used activity during local university-sponsored outreach events, they have also proved popular among area teachers and are regularly borrowed for classroom use. Over the 2017–2018 school year, our CT Bins effort expanded with a series of professional development workshops hosted across the state. Sets of ten curated bins were left at multiple regional educational service centers with the support of a Google grant. By physically distributing sets of these bins across the state, we increase availability and convenience for teachers and schools outside the immediate region around our university.

Through the CSTA National Convention, the CT Bins received national exposure and were well regarded. By publishing this work, we hope to expose even more potential users to the benefits and advantages of CT Bins.

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