Engagement in Practice: Outreach Program to Introduce Computer Science to Middle School Students

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I. Abstract

Research continues to show a consistent decline in the number of students entering the field of Computer Science (CS) (Ali and Shubra, 2010). Studies also indicate that an optimal time to promote interest in CS is during the middle school years (Tai, Liu, Maltese, and Fan, 2006). Yet, most CS courses are only offered as electives, which are not required for graduation (Urness and Manley, 2013). This makes fostering interest in CS at an early age even more challenging. However, some programs, such as the Alice Camps, have successfully encouraged interest in the subject for middle school students (Adams, 2007).

Recently, we completed a community outreach program to provide CS classes to local Title I middle school students attending a summer camp. The authors taught hour-long CS classes to four groups of students. The purpose of the classes was to boost interest in CS by teaching students basic computer programming concepts. The students were also educated about careers that require this skill set and were introduced to a programming language called "Processing". We observed that students showed increased enthusiasm towards CS. In addition, we noticed that the group activity component of the classes encouraged sociability and idea synthesis among peers. This CS community outreach program motivated us to extend the effort to teach science concepts using the Processing language. This may potentially promote sociability, creativity, and empowerment in STEM among middle school students. Specifically, we plan to use the Processing programming language to facilitate learning of biological and chemical concepts, since such concepts can be difficult for students to visualize from a textbook. This paper provides details on other researchers' relevant work in this area, the use of the Processing programming language, and our plan for data collection and analysis.

II. Background

Moreno, Tharp, Vogt, Newell, and Burnett (2016) reported that the middle school years are an important stage for encouraging curiosity in Science, Technology, Engineering, and Mathematics (STEM) professions. Despite this, not all students in the US are given the chance to participate, study, and succeed in STEM-related subjects during the middle school years. Engineering, specifically, is often overlooked in most middle school curricula, since it is generally not a part of core science or mathematics courses (Moreno et al, 2016). These disparities in access to opportunities for STEM education adversely affect student progression in these fields and, are particularly detrimental to students in schools located in economically disadvantaged communities (Igualada, 2015).

In response to the lack of access to computer science in middle school curriculum, Mouza, Marzocchi, Pan, and Pollock (2016) explored the teaching of CS through extra curricular activities. This program was created via cooperation among the university faculty, undergraduate students, middle school teachers, and middle school students. Fifty-two middle school students participated in a nine-week after-school program. They found that students learned CS substantially and were able to do CS exercises as a result of participating in this after-school program (Mouza et al., 2016).

The learning activity central to this paper was conceptualized as an opportunity to boost curiosity for careers in CS by teaching students basic computer programming concepts and educating them about careers that require this skill set. The lesson was grounded in constructionism, deviating from traditional ways of teaching CS. Berland, Baker, and Blikstein, (2014) found that constructionist-learning theory is a formable basis for teaching complicated concept to beginners. Constructionism suggests that by empowering learners to create inventive products requiring a complicated concept to function, learners will subsequently learn a concept (Berland et al., 2014). Nugent, Barker, Grandgenett, and Welch (2016) proposed that a learning environment that incorporates variety in its objectives and structure encouraged STEM learning. In addition, the results of their study suggested that including camps, contests, and clubs in their summer camps also promoted positive mindsets towards STEM (Nugent et al., 2016).

Chang, Quintana, and Krajcik (2010) explored whether student comprehension of the particulate nature of matter was enhanced by having them design and assess molecular animations of chemical events. These researchers created a student-focused animation tool named Chemation. This tool allowed seventh-grade students to create plain animations to demonstrate molecular models and movements. Chang et al. (2010) randomly selected 271 students from eight classes and divided them into three test groups. Each of the three groups utilized Chemation. Test group 1 used Chemation to design, understand, and assess animations. Test group 2 utilized Chemation to design and understand animations only. Test group 3 used the tool to only examine and understand animations created by teachers. The students in Group 1 performed better than students in Groups 2 and 3. Results of this study showed that the design method combined with peer evaluation of animation by students was a successful way to use animations for teaching purposes (Chang et al., 2010).

In our previous research paper, we reported our intention to develop a prototype for an adaptive learning system (ALS) to raise STEM interest in middle school students (Islam, Shankar, Freytag, and Serrano, 2015). We envisioned utilizing engineering approaches to create predictive models to help and guide students. This current study will form the underlying pedagogical process to evaluate our ALS prototype.

III. Processing Programming Language

Weintrop and Wilensky (2015) found that there are multiple disadvantages to blocks-based programming when compared with text-based programming. Students learning with blocks-based programming were able to complete fewer tasks, as compared to students learning with text-based programming. In addition, some students stated their doubts about usefulness of blocks-based programming to execute real programming tasks (Weintrop and Wilensky, 2015).

Tsukamoto, Takemura, Nagumo, Ikeda, Monden, and Matsumoto (2015) utilized a textual programming language to teach programming to 4^{th} and 5^{th} grade students in two subsequent weekend classes to develop a feeling of enjoyment and elation and to instill a longing to participate in programming. Each class was one hour in duration. Based on their results, these researchers suspect that with proper course contents, 4^{th} and 5^{th} grade students could find programming using textual programming delightful. Processing is a textual programming language. In addition, they suggested that this could potentially be observed in students in other grades as well (Tsukamoto et al., 2015).

Recently, we taught approximately sixty students to use the Processing programming language while they attended summer camp. The students were approximately 12 years of age and planned to begin the sixth grade in a local middle school after the summer. Reas and Fry (2007) started this programming language and its development environment as an open source project. Processing programming language is frequently utilized to create innovative and artistic programs (Reas and Fry, 2007; Colubri and Fry, 2012). We used the 'Hello Processing' tutorial and an online processing editor (Shiffman, Garner, Chorng, Mooney, Murray, and Reas, 2013) to introduce students to the Processing programming language. Students used this programming language to write their names, draw geometric shapes, and add colors to background, text, and shapes. Groups comprised of two or three students worked together using a desktop computer. Some groups took turns with the computer, while other groups had one student who typed while other students watched and provided assistance with the assignment.

Throughout the sessions, we observed a variety of behaviors by the students. We observed that some students desired to continue working when the hour-long session had ended. We noted that some students were not willing to share the computer time with their group members, choosing instead to use the computer by themselves for the whole session; others had a more expansive view and explained the Processing programming language concepts to their group members. Several students expressed an interest in learning more about programming.

Overall, students were engaged in the programming activities. We heard encouraging questions and comments, such as (1) "How do I move this rectangle from here to there?" (2) "How do I change the color?" (3) "What else can I do?" (4) "I like to code" (5) "Coding is fun."

Following interactions between the teacher and students capture some of the dynamics:

Scenario 1:
Student 1: "I don't think I know what's going on."

Student 2: "I get it. Can I show him?"
Scenario 2:
Student 1: "Miss, can I show you what I did? I figured out how to do this."

Scenario 3:
Teacher: "Are you doing okay?"
Student 1: "Yes, I'm just working on adding color and the designs that I want."

Scenario 4:
Teacher: "Who thinks they would do coding later in life?"
Student 1: "I would. I like playing games and now I know a little bit about what its like to code."
Student 2: "I like doing this. It's not hard."

We are developing a prototype to increase students' interest in STEM and improve this framework based on their feedback. Our main STEM objectives are to teach programming, biology/chemistry, and animation. We will explore the following hypothesis: Students in the case group will show improved learning in biology/chemistry compared to the control group. Three types of learning outcomes are to be measured: learning of CS basics (summative); a case-control on learning outcomes for biology and chemistry (self-assessments, summative); and a case-control on sociability, creativity, and empowerment with pre-post tests (self-assessments, formative). We will work with the Fort Lauderdale Museum of Discovery and Science to seek volunteer middle school students with their parents' consent to participate in our after school program. We will randomly assign students equally to the case and control groups. We will provide one lesson per week for one hour for each of the (case and control) groups. We will teach the Processing Programming language to both the control and case groups for 3 to 4 weeks. During the first 6 weeks, we will teach science concepts to the control group using regular teaching lessons, while teaching the case group using our new lesson plan (using the Processing language). We will provide the students with modular code to build applications based on science concepts. After 6 weeks, we will switch the groups and repeat the process. This way, both groups have the opportunity to benefit from our after school program.

Figure 1 below shows excerpt of our processing code that we created for teaching Processing programming language with science concepts. We utilized Processing's object oriented features to make our code modular. The code below shows the setup function. In addition, it shows a class called Element, its constructor, 'display,' and 'share' functions.

```
Oxygen o;

Hydrogen h1, h2;

void setup() {

  size(400, 400);
```

```
  o = new Oxygen(6);
  h1 = new Hydrogen(1);
  h2 = new Hydrogen(1);
}
…..
class Element {
  color c;
  int x, y, w, h, electron;
  Element(color tempC, int wid, int hei, int tempElectron) {
    c = tempC;
    w = wid;
    h = hei;
    electron = tempElectron;
  }
   void display(int x, int y) {
     fill(c);
     ellipse(x, y, w, h);
  }
  float share() {
    return electron;
  }
}…..
```

Figure 1 - Processing Code for Setup Function and Class Element

Figure 2 below shows results of execution of our code. It displays one oxygen atom and two hydrogen atoms. Oxygen has six outermost electrons and requires two more electrons, for a total of eight electrons, in order to complete its outermost cloud layer. This allows the oxygen atom to become stable. Similarly, a hydrogen atom has one electron in its only cloud layer and requires one more electron, for a total of two electrons, in order to complete its cloud layer. This allows the hydrogen atom to become stable. Sharing of electrons between the outermost cloud layer of oxygen and cloud layer of hydrogen atoms allow a water molecule, H_2O, to be created (Atkins, 2015).

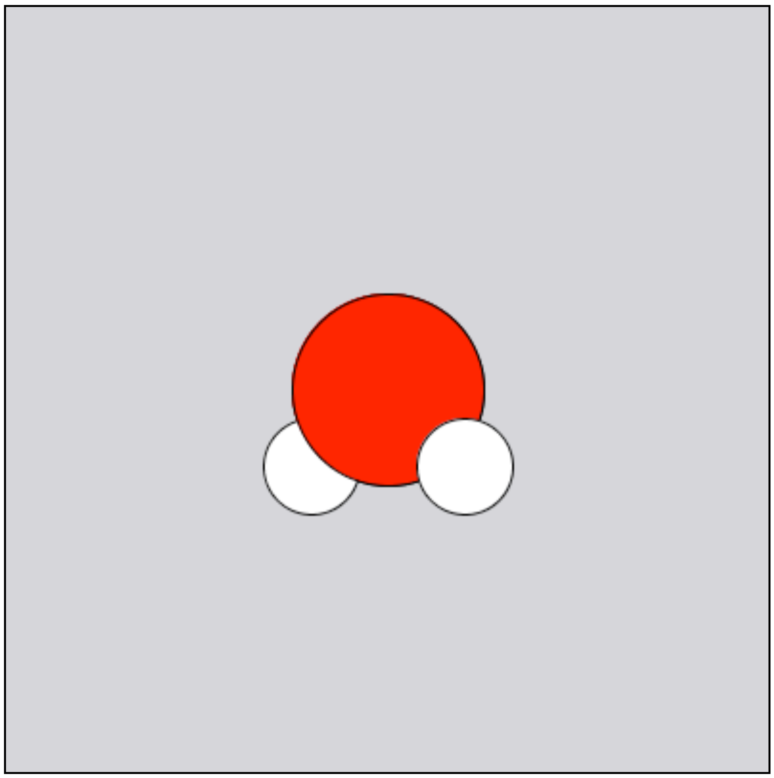

Figure 2 - Output of our Processing Code

IV. Data Collection and Analysis

Kier, Blanchard, Osborne, and Albert (2014) have developed a STEM Career Interest Survey (CIS) that is believed to be psychometrically complete and suited for utilization by STEM researchers, either in part or entirety, as a measurement tool. They utilized the social cognitive career theory to create this survey with STEM categories. To evaluate the survey's reliability and psychometric characteristics, they administered the 44-entry survey to more than 1,000 middle school participants from a rural, low socioeconomic status area in the southern United States. These researchers suggest that STEM CIS will be helpful to other researchers in determining interest in STEM professions and the effects of STEM programs on student interest in STEM fields. Information gathered from using this tool may identify specific changes needed to be made for middle school students in an after school program to increase interest in STEM fields (Keir et al., 2014).

Rai and Singh (2010) indicate that the clustering technique is frequently used as the initial stage in analyzing data. This technique finds sets of similar data that can be utilized as an initial point for identifying additional similarities. This algorithm provides a method to separate students into groups, without prior information about the characteristic of the set (Rai et al., 2010). Cobo, García-Solórzano, Santamaría, Morán, Melenchón, and Monzo (2011) suggest utilizing the agglomerative hierarchical clustering technique. 'Unlike' sets of participants can be found by using agglomerative hierarchical clustering without a priori knowledge of the number of clusters. Additionally, this technique helps with discovering connections among participants combined in one node. These researchers identified that this technique is highly applicable to finding hidden characteristics (Cobo et al., 2010).

Essentially, hierarchical clustering algorithms create clusters in an incremental manner. In hierarchical clustering, the data are not separated into a specific cluster in one step. In its place, a sequence of separations are performed that may execute from one cluster having all the objects to multiple clusters each having one object each. There are two types of hierarchical clustering: agglomerative and divisive. The agglomerative approach continues by sequential steps of combining multiple objects into groups. The divisive approach divides multiple objects in sequential steps into smaller groups. The agglomerative approach is a bottom up technique in which each data begins in its own group and two of the closest groups are joined as they move up the hierarchy until there is just one group left. Therefore, this algorithm will produce a binary cluster tree with one particular cluster as its leaf nodes and a root node comprising all the data (Rai and Singh, 2010). Species taxonomy is a classic illustration of the agglomerative approach (Atiq, Ingle, and Meshram, 2012). Swedish botanist, zoologist, and physician, Carl Linneaus is recognized as the "father of modern taxonomy." Using a combination of logic and biology, he created a system, which later developed into the contemporary method for classifying organisms based on levels of difference from the most specific category, species, to the broadest category, Kingdoms (Calisher, 2007).

V. Summary and Conclusion

We are creating an after-school pilot study to teach science concepts with the Processing programming language to local middle school students. Our goal is to increase student interest in STEM fields while promoting sociability, creativity, and empowerment in those subject areas. We will utilize the Processing programming language, science concepts, and animation to create lesson plans. We will recruit middle school students with the help of the Fort Lauderdale Museum of Discovery and Science. We will initially leverage the STEM Career Interest Survey and content assignments to measure students' interest in STEM. We will primarily utilize agglomerative hierarchical clustering algorithm to group students based on their interest level and activities. We will share our findings in our next research paper.

Acknowledgments: The authors wish to thank Dr. Perambur Neelakantaswamy, Dr. Ionut Cardei, Dr. Dingding Wang, and the Fort Lauderdale Museum of Discovery and Science.

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