# Pedagogy of CS Unplugged: Lessons from Outreach and Education Activities in Computer Science

**Aubrey Lawson**
Clemson University
Clemson, SC, 29631, USA
aubreyl@clemson.edu

**Eileen Kraemer**
Clemson University
Clemson, SC, 29631, USA
etkraem@clemson.edu


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## Introduction

Data physicalization (or Physicalization) has been defined as a "physical artifact whose geometry or material properties encode data"[7]. Organizers of the *Pedagogy & Physicalization* workshop state in the workshop call that Physicalization has been found useful in introducing people to activities around data collection, processing, and representation, and identify reflection on related pedagogy as a major goal of the workshop.

*CS Unplugged* (*CSU*), a collection of activities designed to demonstrate computer science (CS) concepts to K-12 students in a fun and engaging way and without using computers[1] also seeks to convey knowledge about data collection, processing and representation. *CSU* activities employ Physicalization (objects of various types are used to represent elements of data collections) and are also typically collaborative and kinesthetic (e.g., students may change seats, move physical objects, walk from station to station, hold up cards with dots, etc.). Thus, *CSU* is related to Physicalization. However, while the Physicalization community has focused primarily on research questions surrounding the design and impact of appropriate and compelling physical representations for data sets of interest, the *CSU* community has placed more emphasis on designing activities that engage students and convey knowledge about the *processing* of data and on technical rather than aesthetic aspects of data representation. Still, lessons learned from empirical studies of *CSU* activities may be applicable to Physicalization and reflections on connections between CSU activities, outcomes of empirical studies, and learning theory may be of interest to the Physicalization community.

The use of *CSU* activities for outreach is prevalent in the computing education community, as described in papers such as [1], and belief in the impact of these activities is widespread. More recently, such activities have also been assumed to be beneficial in an educational context and they have been included in regular computing curricula. In the following sections we describe how *CSU* activities have been employed in these contexts and briefly describe results of empirical studies that evaluate their impact. We then discuss connections to learning theory and possible implications for Physicalization in both outreach and educational contexts.

## *CSU* as an Outreach Activity

CS Unplugged materials have been adopted into a variety of outreach settings (camps, workshops, after-school programs) focused on affecting student views about the nature of computer science and the characteristics of those with the potential to become computer scientists, and encouraging participants to study CS or to pursue a career in computing [1, 2, 4, 6, 8, 11, 10].

Researchers who studied the impact of such outreach activities found that middle school girls exhibited increased interest in CS as a result of participation [8, 6]. However, the studies suffered from confounding factors such as self-selection and the inclusion of non-*CSU* subject matter.

Further explorations of student views, attitudes, and intentions concluded that *CSU* activities "start a process of changing the students' views, but that this process is partial" and found also that students had difficulty in making connections between *CSU* activities and concepts in CS [11] and between *CSU* activities and future careers [10]. Studies of *CSU* activities with high school students found disinterest from both students, who may view themselves as “experienced programmers” and as too mature for this style of activity [4], and from teachers, who cited concerns about the kinesthetic aspect, effectiveness, and age appropriateness [14].

In summary, although belief in the impact of *CSU* activities is prevalent, empirical studies to date are mixed; smaller studies with potentially confounding factors report great success, while larger and more carefully conducted and documented studies report fewer increases in desired changes in views and attitudes, or even a decline in interest. More work to tease out the circumstances under which *CSU* activities may be used to achieve desired changes in student views, attitudes and intentions is needed.

## *CSU* in Classroom Instruction

Increasingly, the notion of applying *CSU*-style activities in the context of regular classroom instruction is gaining traction in the CS education community. An open question is whether this is appropriate and if so, how these activities must be structured and supported to ensure that desired learning objectives are met.

Studies of the use of *CSU* activities in an educational context have included analyses of the learning objectives of *CSU* activities in terms of Bloom's taxonomy[12], comparisons of student learning in *CSU*-based lessons versus in lessons using other active learning approaches[13], and evaluations of the use of *CSU* activities as introductory units in longer, traditional teaching units[14].

The analysis of the *CSU* activities according to Bloom's taxonomy of educational objectives for cognitive and knowledge domains found that the activities were concentrated toward the lower levels of both knowledge and cognition and that the more complex dimensions had little to no representation: no activities qualified for meta-cognitive knowledge, few for evaluative cognition, and none for creative cognition[12]. The authors conclude that their classification "explains and supports" the success of *CSU* for outreach purposes (no cognitive inhibition threshhold is reached by participants) but that it also shows that the use of *CSU* in an *unmodified* form as stand-alone material for teaching concepts at a secondary level is "limited" because the learning objectives of *CSU* activities neither provide comprehensive representation of the field nor do they cover the cognitive processes and types of knowledge that are needed in this context.

In an evaluation of the use of *CSU* activities to teach middle school students about binary representation, the binary search algorithm and sorting networks, *CSU* was compared to the use of another active learning technique (e.g., think-pair-share) on the learning of factual, procedural and conceptual knowledge[13]. No significant difference was found between the groups.

More recently, the same researchers again compared non-*CSU* approaches to an approach in which *CSU* activities were used as introductory material in a longer, traditional teaching unit[14]. Once again, no statistical difference between learning outcomes was found between those taught with *CSU* and those taught with traditional methods.

Researchers have proposed compensating for the lack of content hierarchy and assessment material in *CSU* by encapsulating *CSU* within formalized lesson plans [14, 9]. Rodriguez, et al. isolated specific factors key to successful implementation, including priming activities, individual practice, vocabulary worksheets, and relevant tie-ins to real world contexts [9].

## Discussion

By promoting student interaction with physical representations of data and processes, *CSU* activities incorporate active learning and serious play into CS education. Students take ownership of their learning and personalize it as they interact with the environment. The hands-on, kinesthetic component exploits multi-channel input[3], and the visual and verbal cues provided should allow students to benefit from richer cognitive networks and content acquisition [3]. Physicalization also enables collaboration and peripheral participation as students can learn by observing other students' interactions with artifacts.

While *CSU* and Physicalization capitalize on learning theory with an active, collaborative, and constructivist environment, students need appropriate guidance for content knowledge schema acquisition. Physical artifacts provide tangible analogies for CS concepts, but analogical reasoning proves more difficult than expected for novices [5]. Kinesthetic activities can also fall into lower classifications along Bloom's taxonomy for learning outcomes, as students may be preoccupied with tinkering and working out procedures without focusing on meta-cognitive knowledge and evaluative cognition [12]. Age appropriateness remains a concern for teachers who express hesitation to implement detailed physical representations of data or to employ kinesthetic methods [4, 14].

As *CSU* popularity grows, implementations have brought mixed success and concerns remain about bridging *CSU* activities into classroom instruction. An open question is whether the same concerns about the extent to which students are able to engage in analogical reasoning, learn the desired concepts, and transfer those concepts to other domains apply to the pedagogy of Physicalization.

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