Examining the Impact of Student Choice in Online Science Investigations

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Abstract: Incorporating choice into instruction can promote learning that builds upon learners' prior knowledge and interests. We present our results from the combined analysis of data collected across six classroom comparison studies investigating the impact of choice-based curriculum units with middle and high school science students. By "choice" we mean that students are able to decide for themselves which investigation modules (among a curated set of options offered within the curriculum unit) to complete to advance their understanding. Analysis of the combined data set (total N = 661) revealed a significant difference in overall pre-to-post learning gains in favor of students in the choice condition (compared to students in the no-choice, or standard condition). Our findings provide evidence for the value of implementing student choice compared to typical instruction that assigns students to learning activities in a predetermined sequence regardless of learner preference or interest.

Keywords: science education, technology-enhanced learning, instructional design

Introduction

In this paper, we investigate the impact of online science curriculum units that incorporate opportunities for students to guide their own learning through choice. We present findings from the analysis of data collected across six classroom comparison studies implementing two choice-based curriculum units (*Investigating Seasons* and *Global Climate Change*) with middle and high school science students (total N = 661). By "choice" we mean that students are able to decide for themselves which investigation modules (among a curated set of options offered within the curriculum unit) to complete to advance their understanding of the unit topic (either seasonal temperature variations or rising global temperatures). The activities and virtual models in the *Investigating Seasons* and *Global Climate Change* curriculum units were designed from a constructivist perspective, meaning that learning is viewed as an iterative process of constructing more sophisticated understanding through instruction that acknowledges and builds upon a learner's prior ideas and knowledge (Smith, diSessa & Roschelle, 1993). With this work, we propose that providing choice during instruction can prompt students to consider their prior ideas and understandings before choosing, making the learning experience not only more personally relevant but more impactful. Our combined analysis of the classroom studies conducted with the *Investigating Seasons* and *Global Climate Change* curriculum units described in this paper investigate the research question: How does providing choice impact student learning compared to standard instruction without choice? Taken together, these studies provide insight into the effect of choice-based curriculum units on student learning as measured by conceptual gains assessed by the validity and sophistication of their written explanations.

Background

This work is motivated by the research literature examining the beneficial impact of choice on students' sense of agency, relevance and engagement during learning and other cognitive tasks. Pintrich, Marx and Boyle (1993) noted that the typical structure of instruction in classrooms, in which students are given little choice or control over their learning activities, was less likely to support the development of an intrinsic desire to gain knowledge. Conceptual change was found to more likely occur for students with an intrinsic, or mastery orientation towards learning (Pintrich & De Groot, 1990). However, many students in today's science classrooms continue to experience scientific inquiry as a linear, step-by-step "cookbook" endeavor (Chinn & Hmelo-Silver, 2002). All students learn the same material in the same manner through a prescribed sequence of instructional steps. Offering different investigation choices for students to choose from can make the learning experience feel more personally relevant (Cordova & Lepper, 1996; Katz & Assor, 2007), which can in turn lead to more effortful and self-regulated learning (Flowerday, Schraw, & Stevens, 2004). Although the role of choice has been studied for a number of educational contexts and topics, studies investigating the impact of choice for a challenging conceptual learning endeavor such as scientific inquiry are still rare (refer to: Reber, Hetland, Chen, Norman, & Kobbeltvedt, 2009). This research contributes to the existing body of work by examining the feasibility and impact of choice embedded in an inquiry curriculum unit that supports students' in developing evidence-supported explanations for a complex scientific phenomenon (such as seasons or global climate change).

Methods

The design of both the *Investigating Seasons* (abbreviated as *Seasons*) and *Global Climate Change* (abbreviated as *GCC*) curriculum units was guided by the knowledge integration (or KI) constructivist framework for instruction, which acknowledges that students hold varied ideas about scientific phenomena. The KI framework specifies that helping learners to develop a more robust and sophisticated understanding involves four processes: eliciting students' prior ideas about a phenomenon, providing opportunities for the addition of ideas to students' repertoire, supporting students in making distinctions among their various ideas, and guiding students to reflect upon their developing understanding (Linn & Eylon, 2011).

Design of choice curriculum units

For both *Seasons* and *GCC*, we developed a choice and standard version of the curriculum unit. For the choice version of the units, students are prompted to choose for themselves which modules (from a curated set of options) to complete (Figures 1 and 2). In both units, choice was framed as an opportunity to either investigate a topic based on relevance or interest to the student. In contrast, the standard version for both units does not provide choice and instead assigns students modules to complete without consideration of interest or preference (similar to typical instruction). For the choice version of the *Seasons* curriculum unit, students can gather data from interactive models in five different modules to explore up to five possible causes for seasonal temperature variations. The standard version of *Seasons* presents the modules in a predetermined order (as a teacher might do in implementing a series of lessons for the topic). In the choice version of the *GCC* curriculum unit, students select three different options (out of six possible modules) for using a model to investigate potential causes for rising greenhouse gases and global temperatures. For the standard version of *GCC*, students are assigned three of the modules to complete.

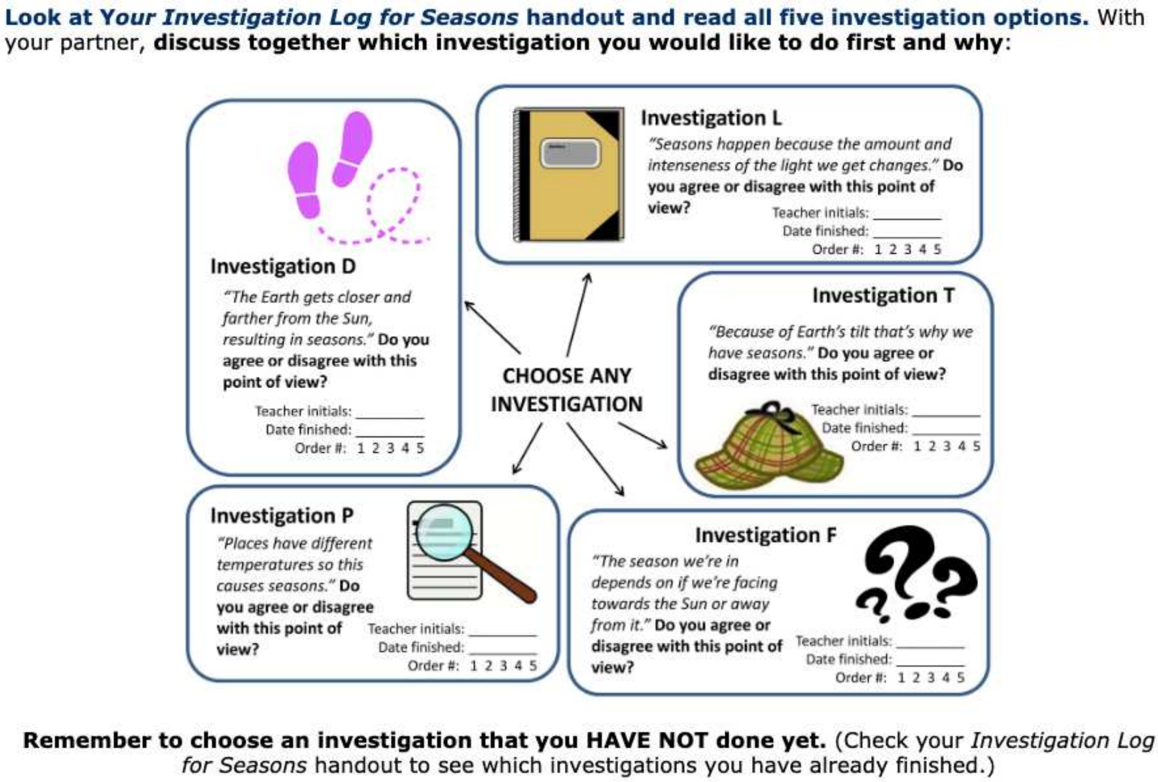

Figure 1. Screenshot of the module choice page from the *Seasons* curriculum unit.

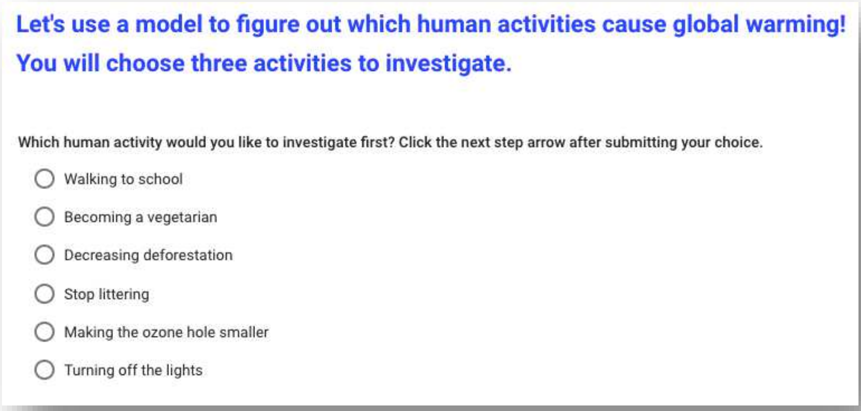

Figure 2. Screenshot of module choice page from *Global Climate Change* curriculum unit.

Study design, participants and assessments

For each classroom study, students were randomly assigned to complete either the choice or standard version of the curriculum. In total, 661 students participated in either a *Seasons* or *GCC* classroom study (Seasons N = 164 and GCC N = 497). Student learning from the *Seasons* and *GCC* curriculum units was assessed using pretest and posttest open-response assessment items administered before and after completion of the respective unit. For *Seasons*, students were given the prompt: *Write an explanation that clearly explains what causes seasons. Use as much evidence as you can in your explanation.* For *GCC*, students responded to two items: The first item asked students to explain how the temperature inside a car would compare to the temperature outside on a cold but sunny day (a situation similar to the greenhouse effect). The second item asked students to explain the actions they could take to minimize their impact on global warming. Together, these two items examine students' conceptual understanding of the mechanism of global warming and the connections students make between that understanding and their own daily activities. For each assessment item (whether *Seasons* or *GCC*), we scored student responses on a scale from 0-4 using a knowledge integration (KI) rubric (Linn, Lee, Tinker, Husic, & Chiu, 2006) that rewards the scientifically valid connections students make between ideas. For the combined analysis data set, an average KI score for the two scored *GCC* assessment items was calculated for each *GCC* student.

Results and discussion

We have reported previously on the results of our *Seasons* (King Chen, 2013; 2016; King Chen & Linn, 2019) and *GCC* (Bradford, McBride, Bland, & Linn, 2019) choice studies separately. Our previous results did not find any significant differences for student learning gains between the choice or standard condition, although for both the *Seasons* and *GCC* analyses we observed a consistent trend in favor of choice for different learning measures, including: overall pre-to-post learning gains, the scientific validity of the explanation and time students spent on deciding which module to choose. Consequently, for this paper we combined the *Seasons* and *GCC* data sets to see if a larger sample size might provide insight into the effect of choice on student posttest gains. A one-way ANCOVA with pretest score as a covariate and choice condition as a factor was conducted to examine the effect of the choice condition on student learning outcomes. There was a significant difference between students in the choice and standard conditions ($F(1, 568) = 3.90$, $p = 0.049$, $\eta^2 = 0.007$). There was a slight advantage in posttest gains for students who had the opportunity to choose their investigation modules ($M = 1.96$, $SD = 0.89$) over those who had their investigation modules assigned ($M = 1.91$, $SD = 0.90$). Furthermore, during classroom observations of teacher use of the *Seasons* and the *GCC* curriculum units, we observed that teachers had differing styles and varying levels of proficiency with facilitating student use of the curriculum and engaging with students' expressed ideas. To examine the effect of teacher implementation style and if it provided a differential advantage to students in the choice condition, we conducted a two-way ANCOVA with pretest as a covariate and teacher and choice condition as factors. The teacher by choice interaction term was insignificant ($F(5, 558) = 0.48$, $p = 0.791$, $\eta^2 = 0.004$). This indicates that none of our teacher implementation styles yielded an additional benefit for their students that enhanced the effect of choice. Significant main effects for both the choice condition ($F(1, 558) =$

4.86, $p = 0.023$, $\eta^2 = 0.009$) and teacher ($F(5, 558) = 17.7$, $p < 0.0001$, $\eta^2 = 0.137$) were observed, suggesting that while choice-based curriculum is beneficial for student learning, the overall implementation of curriculum by the teacher is an important factor to consider as well.

Conclusions and significance

In this paper we presented our classroom studies using the *Seasons* and *GCC* curriculum units as instantiations of choice-based online instruction for supporting students in their investigations using virtual experimentation models. Our findings suggest a learning benefit for designing for and implementing student choice compared to typical instruction when students are assigned a prescribed sequence of learning activities. However, important design and implementation considerations for choice-based science projects to consider include: How can we design choices that are especially meaningful and relevant for learners? How can we support teachers in successfully utilizing choice-based instruction in their classrooms? This work finds value for choice-based instruction, demonstrating its potential for supporting student learning in not only different science discipline contexts but for different grade levels (middle and high school). Our findings suggest the need to better understand how teachers facilitate student interaction with online curriculum as well as how best to support students in engaging with choice-based instruction. Providing choice can engage learners in more self-directed, open-ended and nonlinear instruction, resulting in more effective learning experiences for students. A choice-based model of learning strives to be relevant and engaging for different individuals, and is likely to appeal and motivate more than instruction that remains designed from the perspective that "one size fits all".

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