Inq-ITS Supports Students Maintaining their Science Inquiry Competencies during Remote Learning due to COVID-19

Objective

Although prior research on remote instruction exists (Brinson, 2015; Heradio et al., 2016), the COVID-19 crisis provides a unique context to investigate how an unexpected switch to remote instruction affects learning in difficult domains, such as science inquiry. The present study explores students' science inquiry practice performances in Inq-ITS virtual labs prior to and during remote learning due to the COVID-19 pandemic. Specifically, we examined how a sophisticated educational platform that assesses students' inquiry at a fine-grained level and scaffolds them in real time may support students even under extreme circumstances.

Theoretical Framework

In the spring of 2020, in order to abate the spread of the COVID-19 pandemic, schools worldwide temporarily closed, affecting over 90% of the world's student population (UNESCO, 2020). In response, most schools chose to continue instruction remotely, using a multitude of online tools and resources. With continued uncertainty about the future of educational institutions, innovations from the field of educational technology and online learning offer support for teachers, students, and parents (Ferdig et al., 2020; Zhou et al., 2020).

A major challenge that arises with remote instruction during the pandemic is the lack of opportunities for in-person assessment and scaffolding opportunities (Reimers & Schleicher, 2020). There are even more challenges to be considered when it comes to online instruction in *science* in particular, including the time, cost, and safety concerns associated with setting up physical experiments at home (D'Angelo et al., 2014; Finkelstein et al., 2005; Kuhlman, 2015; Martinez-Jimenez et al., 2003). It is essential, however, for students to have rich scientific experiences in order to master inquiry practices such as asking questions, carrying out investigations, and analyzing and interpreting data, as outlined in the Next Generation Science Standards (NGSS, 2013); nonetheless, these practices are challenging for students to master without support (Hmelo-Silver et al., 2007). Additionally, assessment and tracking of students' inquiry practice competencies is critical not only because teachers use data from assessments to adapt instruction and support students' learning, but also because it is necessary to measure student growth throughout the school year. However, assessing inquiry practice competencies, even in typical classroom contexts, is difficult because (a) multiple-choice tests cannot fully reflect students' competencies required by the Next Generation Science Standards (NGSS, 2013; Gobert et al., 2013) and (b) written lab reports can be inaccurate due to the writing skills required to complete these reports (Li et al., 2017a). Fortunately, developments in technology for science assessment and learning, when enabled by educational data mined algorithms, have the potential to address both teachers' assessment challenges and students' learning needs.

Though middle and high school students perform as well on science inquiry practices when engaging with virtual experiments in the classroom as with physical hands-on experiments (Brinson, 2015; Heradio et al., 2016; Pyatt & Sims, 2012), most studies have not explored student performance on virtual labs when there is no immediate access to in-person classroom support. Additionally, most virtual science labs do not provide both real-time assessment and individualized scaffolding to students on a range of inquiry practices as does Inq-ITS, which permits students to complete inquiry tasks in a completely remote setting. Designed to align with the NGSS (2013), the virtual labs and simulations in the Inq-ITS intelligent tutoring system platform alleviate the practical concerns (i.e., safety, equipment, etc.) associated with physical experiments. Importantly, these labs also support students' development of the science inquiry practices over time (Li et al., 2019) and assess their competencies at a fine-grained level using patented, educational data-mined algorithms (Gobert et al., 2013) that have been validated in prior studies (Gobert et al., 2013, 2018).

The unique situation of schools suddenly adopting a remote-learning model allows us to investigate how that switch affected middle school students' performance on science inquiry tasks. To this end, we sought to investigate the pattern in student performance on science inquiry practices in Inq-ITS as a result of the sudden change to remote instruction due to COVID-19. In particular, how do students' performances on inquiry practices change with the switch to remote instruction when students have continued access to real-time, personalized scaffolding in Inq-ITS virtual labs throughout the 2019-2020 school year?

Methods

Participants

The participants in the present study included six middle school science teachers and their students (N = 259 students). These teachers and students were from five different middle schools across the United States (see Table 1 for school demographics). The participants were identified retrospectively based on the following criteria: 1) teachers had at least one year of experience with the Inq-ITS system prior to the 2019-2020 school year, 2) teachers assigned and students completed at least 2 virtual labs in Inq-ITS in their physical classrooms during the 2019-2020 school year prior to the COVID-19 pandemic, and 3) teachers assigned and students completed at least 1 additional Inq-ITS virtual lab with scaffolding remotely during the 2019-2020 school year once schools were closed due to the COVID-19 pandemic (see Procedure section for further details).

Materials

Students completed virtual science labs in the intelligent tutoring system, Inq-ITS. Inq-ITS virtual labs were designed to align with the science inquiry practices outlined in the NGSS (2013). In particular, when using Inq-ITS labs, students advance through various stages of a scientific investigation. The first stage involves asking questions, or hypothesizing, during which students form a question to investigate in relation to a larger scientific question. The second stage involves carrying out investigations during which students collect data by manipulating variables, running experimental trials in a simulation, and storing data from the trials in a table. Third, students analyze and interpret data by making a claim about the scientific question based on the findings from the investigation and selecting evidence collected to support the claim; students can also return to collect more data and move through the stages in a non-linear fashion. In the last stage of the lab, students communicate findings by writing statements in a claim, evidence, and reasoning (CER) format based on the findings from their investigation; automated scaffolding is still being developed for this stage (Li et al., 2017b). A pedagogical agent, Rex, is available to provide automated scaffolding to support students during each of the first three stages of the Inq-ITS labs. Rex will appear on the students' screen with increasing levels of support (see Table 2) if the student continues to have difficulty on an inquiry practice, which is determined by the automated scoring in Inq-ITS (see Measures section for further details).

Procedure

There are currently over 65,000 users in the Inq-ITS database. All data from middle school teachers who assigned activities in Inq-ITS to students in both 2018-2019 and 2019-2020 was pulled from the database. This decision was made in order to ensure that teachers were highly familiar with the Inq-ITS system due to the retrospective nature of the present study. We then identified all teachers who assigned and had students complete at least one Inq-ITS virtual lab with scaffolding from Rex during remote instruction due to the COVID-19 pandemic and removed teachers who did not assign labs during the pandemic. To allow for a comparison of student performance before and during remote instruction, we then identified teachers who assigned and had students complete at least two virtual labs before the start of remote instruction and removed all teachers from the data set who only assigned labs during remote instruction. We looked for teachers who assigned at least two labs because the initial lab would serve as a tutorial for students to the Inq-ITS system as in prior studies (Li et al., 2019).

After cleaning the data based on the above criteria, there were six teachers remaining in the data set. We then pulled the student performance data on inquiry practices in the Inq-ITS virtual labs that were completed prior to and during remote instruction (see Measures section for details on automated scoring in Inq-ITS).

Measures

Inq-ITS utilizes previously validated educational data mined and knowledge engineered algorithms to automatically assess students' competencies with the science inquiry practices of asking questions (i.e., hypothesizing), carrying out investigations (i.e., collecting data), and analyzing and interpreting data (Gobert et al., 2013, 2018; Li et al., 2017a, 2017b; Moussavi & Gobert, 2016). Students' scores on these inquiry practices range from 0 (lowest) to 1 (highest) and are determined by fine-grained sub-components aligned to the NGSS (2013) that have been developed and tested iteratively in prior studies (Gobert et al., 2012, 2013, 2018; Li et al., 2017a, 2017b; Moussavi & Gobert, 2016).

Analyses

A repeated measures MANOVA was used to examine students' inquiry practice performance before remote learning to during remote learning as a result of the COVID-19 pandemic. Specifically, the within-subjects dependent variables being examined included student performance on the three inquiry practices automatically assessed in Inq-ITS: hypothesizing, collecting data, and analyzing data. Time was used as the independent variable with two levels: before COVID-19 (i.e., prior to the period of state-designated remote learning) and during COVID-19 (i.e., during the period of state-designated remote learning).

Results

A repeated measures MANOVA was used to test for changes in student performance from before to during remote instruction. In particular, we were interested in whether students' performances on the inquiry practices were maintained or even improved when students had access to scaffolding from Rex in Inq-ITS during remote instruction due to the COVID-19 pandemic. A significant within-subjects effect was found for the overall model over time, $F(3, 256) = 16.98$, $p < .001$, $\eta^2 = .17$. In terms of the main effects, there was a significant within-subjects effect for collecting data over time, $F(3, 256) = 19.47$, $p < .001$, $\eta^2 = .07$. Specifically, students significantly improved on collecting data from before remote learning ($M = .69$, $SD = .28$) to during remote learning ($M = .79$, $SD = .31$). Additionally, there was a significant within-subjects effect for analyzing data over time, $F(3, 256) = 46.10$, $p < .001$, $\eta^2 = .15$. Specifically, students significantly improved on analyzing data from before remote learning ($M = .65$, $SD = .22$) to during remote learning ($M = .76$, $SD = .25$). There was no main effect for hypothesizing, $F(3, 256) = .14$, $p = .711$, $\eta^2 = .01$, because students maintained their performance from before remote learning ($M = .79$, $SD = .17$) to during remote learning ($M = .79$, $SD = .25$).

These findings demonstrate that, when students were provided with a system that is instrumented to assess and scaffold their inquiry competencies on a fine-grained level, they maintained or significantly improved their inquiry practice performance from before to during remote learning due to the COVID-19 pandemic. Despite the challenges presented during the sudden switch to remote learning, the rich virtual labs in Inq-ITS and the corresponding automated scaffolding from Rex played a key role in supporting student learning, providing further evidence for the power of educational technology, such as Inq-ITS.

Scholarly Significance

There is a prevalent need for online technologies for remote instruction (Reimers & Schleicher, 2020), and these results show that with access to scaffolding from Rex on the virtual labs in Inq-ITS, middle schools students maintain and continue to improve their performances on the science inquiry practices. Students and teachers faced many challenges with remote instruction due to the COVID-19 pandemic (Ferdig et al., 2020), and the need for remote instruction will likely continue at least into the 2020-2021 school year. Technologies, such as Inq-ITS that can both assess and support students as they complete activities, are crucial, especially when teachers and students require online resources for remote use (Reimers & Schleicher, 2020) and when inquiry is essential to fostering students' scientific literacy (NGSS, 2013).

Based on these findings, we will further analyze how varying circumstances, such as whether teachers supported their students synchronously or asynchronously as well as the impact of socioeconomic factors, can further explain patterns in student performance. Our next steps include interviewing teachers about their experiences through surveys and extending analysis further to understand the trajectories of students' inquiry practice performances across a broader selection of teachers and students.

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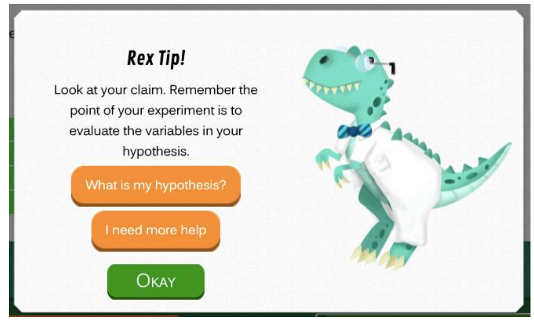
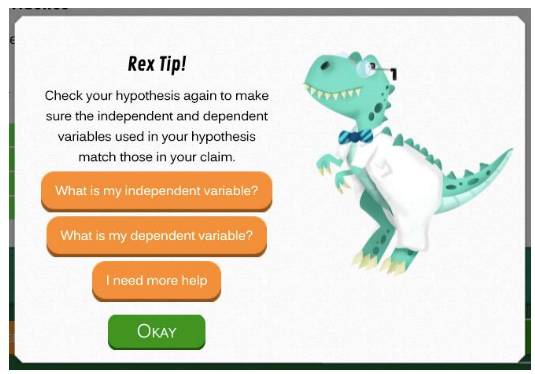
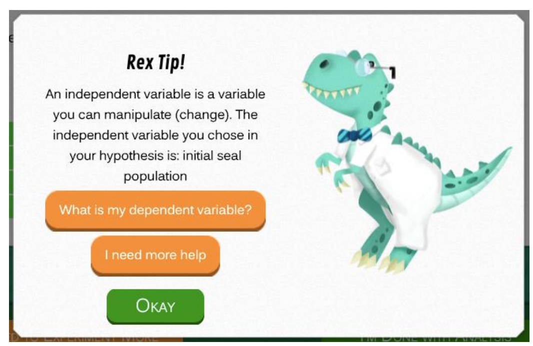
Tables

Table 1. School demographics

School	Teacher	Location	State-mandated COVID-19 School Closure Date	Percent of Students Receiving Free and Reduced Lunch
A	1	CA	March 19	53%
B	2	CA	March 19	37%
C	3	KY	March 16	75%
D	4	NH	March 16	28%
D	5	NH	March 16	28%
E	6	PA	March 16	43%

Table 2. Levels of scaffolding from Rex with examples

Level of scaffolding	Definition	Example of scaffolding for the inquiry practice of analyzing and interpreting data	Screenshot of Rex in Inq-ITS
1. Orienting	Direct the student's attention to a particular practice	Look at your claim. Remember the point of your experiment is to evaluate the variables in your hypothesis.	
2. Procedural	Inform the student of steps involved in engaging in an inquiry practice	[I need more help] Check your hypothesis again to make sure the independent and dependent variables used in your hypothesis match those in your claim.	
3. Conceptual	Define and explain an inquiry practice	[What is my independent variable] An independent variable is a variable you can manipulate (change). The independent variable you chose in your hypothesis is: initial seal population.	
4. Instrumental	Guide the student through the remaining actions to take to complete the inquiry practice	[I need more help] The independent variable in your claim should be: initial seal population. The dependent variable in your claim should be: duration of predation cycles. This makes it so your claim matches your hypothesis.