Students' self-regulated learning skills and attitudes in online scientific inquiry tasks

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Teaching students to think and act as scientists through inquiry is at the core of recent science education. Although self-regulated learning (SRL) is acknowledged as crucial to performing scientific inquiry, much is yet to be understood about the specifics of students' interactions with the scientific process. In the current study, we conducted an exploratory investigation of the role of students' SRL and related attitudes when completing an online scientific inquiry-based task. A task with a Predict-Observe-Explain learning design was used to examine the role of students' SRL and attitudes within specific phases of the scientific inquiry process. Participants were 233 students from an online undergraduate course. Four groups were identified with differing levels of SRL skills, challenge and confidence. We found that students with low SRL skills who also perceived a learning situation as challenging and had low confidence in their ability to learn, had difficulties designing effective experiments and correctly interpreting data. Implications and future studies are discussed.

Keywords: self-regulated learning, scientific inquiry process, digital learning environment.

Introduction

Changes in science curricula in higher education over the past decades towards a more performative conceptualisation have refocused attention on the teaching and learning of the scientific inquiry process. The scientific inquiry process can be conceived of as a series of methods and practices that professional scientists engage with while discovering new knowledge (Pedaste et al., 2015). Learning through inquiry requires self-regulation, that is, "planning, monitoring, and reflecting, which includes being able to plan a research project, monitor your progress, and think about how you could do better next time" (White et al., 2009, p. 176). Although there is compelling evidence to suggest that self-regulated learning (SRL) underpins a number of parts of the scientific inquiry process, much is still to be understood about the specifics of this relationship, particularly in digital environments (Roll et al., 2018). Therefore, the aim of this paper is to examine the role of students' SRL and related attitudes when completing an online scientific inquiry task.

The scientific inquiry process broadly involves formulating a hypothesis, conducting experiments or observations to test that hypothesis, interpreting obtained results and communicating findings to the academic and broader community (Pedaste et al., 2015). Some success in teaching the scientific inquiry process has been found in the use of Predict-Observe-Explain (POE) tasks (White & Gunstone, 1992). A POE task has three parts: (1) students make a prediction based on previous knowledge and known assumptions in the form of a hypothesis, (2) they explore an environment, usually a simulation if the learning environment is digital, where they conduct experiments and observe their outcomes, and (3) they interpret their findings in light of their initial prediction, providing an explanation of the observed phenomenon.

Throughout the scientific inquiry process, particularly when completing POE tasks, students can be viewed as active agents who regulate their cognition, affect/motivation, behavior and context. Broadly speaking, SRL involves three phases: (1) planning, during which students set goals and define strategies to use; (2) monitoring, when students check their progress towards their goals; and (3) regulating, when students make changes to their learning approach, if necessary, to guarantee goal attainment (Pintrich, 2000). Students' attitudes towards learning have been found to impact their ability to self-regulate their learning; particularly, challenge and confidence. Challenge is related to how difficult students perceive a task to be, and confidence (or self-efficacy) is related to how able they feel about learning new content. Perceiving a task as challenging can be motivating to certain students, but not if combined with low confidence. In this case, students' ability to successfully regulate their learning can be compromised.

In the current paper, we present an exploratory study investigating the role of students' SRL (namely, monitoring, regulating) and attitudes (challenge and confidence) when completing a scientific inquiry-based task in a digital learning environment. A task with a POE learning design was chosen to provide a framework in which we could examine the interactions between students' SRL with specific parts of the scientific inquiry process.

Method

Participants were 233 students from a large US-based university enrolled in an introductory Astrobiology online course in foundational concepts in biology, physics and chemistry – called Habitable Worlds – as part of their undergraduate study (Horodyskvj et al., 2018). Habitable Worlds is built on Smart Sparrow, a digital learning platform that affords automatised personalised feedback and captures students' interactions with the system as audit logs. The current study focused on one of the 67 lessons in Habitable Worlds – Brightness. In the Brightness lesson, students learn about the concepts of luminosity, brightness and distance in astronomy, interacting with different tasks across 32 screens. Within this lesson, there is a POE task where students investigate the relationship between brightness and distance.

The POE task has four main screens: Predict, Observe, Analysis and Evaluate. On the Predict screen, students are asked to select a hypothesis about the relationship between distance and brightness. They have five options, with three of these being plausible predictions based on relevant knowledge that students had access to at the outset of this lesson. After the Predict screen, students have the opportunity to check whether their assumptions are plausible. If they select two of the five hypothesis that are not plausible, they are returned to the Predict screen to select a new hypothesis. This cycle continues until the student selects one of the three plausible screens. Therefore, a high number of attempts in the Predict screen can be interpreted as students struggling to identify their assumptions when selecting a hypothesis.

On the Observe screen (Figure 1), students are asked to conduct an experiment to investigate the relationship between brightness and distance. They have access to a simulation where they can position a probe at different distances from the sun (drag and drop) and make an observation, which records on a graph the probe's brightness at that particular distance. Students also mark two checkboxes to indicate they have followed the prescribed methodology. Prior to this screen, students view two tutorial screens with instructions on how to use the simulation. Students are expected to make a sufficient number of observations with a varying range of distances. In case they fail to do so, the system provides students with automated feedback. The available automated feedback options on this screen are: correct, no checklist (students failed to check off the checkboxes), not enough observations (they failed to make the number of observations stipulated earlier in the lesson as the ideal number to be able to make meaningful observations), same observation (they did not make any new observations from the previous tutorial screens, or from previous attempts), and skewed data (they did not have a good range of observations; either too far or too close to the sun). A high number of attempts on this screen can be broadly interpreted as students having difficulty designing and conducting this experiment. The degree of difficulty can be further clarified by examining the type of feedback triggered in the system.

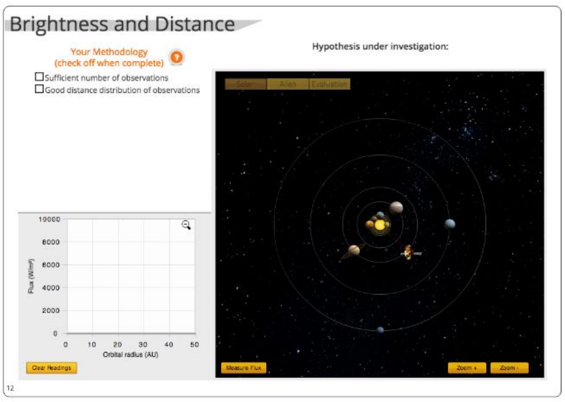

Figure 1: Observe screen in the R*2 Brightness lesson

Both the Analysis and Evaluate screens are related to the Explain phase of the POE task (Figure 2). On the Analysis screen, students are asked to interpret whether their observations match their initial prediction. Students then receive personalised feedback based on whether they made an incorrect match (answering that their observations matched their prediction, when it didn't; or vice-versa) or had difficulty using the graph to interpret their results ("no points visible" option). In both cases, students stay on the current screen for further attempts based on the feedback received. A high number of attempts on the Analysis screen can be interpreted as either students' having difficulty interpreting their observations (incorrect match) or having difficulty manipulating the graph (no points visible).

On the Evaluate screen students are asked to either accept or reject their initial hypothesis. On this screen, they are asked to interpret their observations in a formal manner as usually stated in scientific reports: accept or reject a hypothesis. Students stay on the current screen for further attempts if they have rejected a correct hypothesis or accepted an incorrect hypothesis. Conversely, they move to the next screens once they have either accepted a correct hypothesis or rejected an incorrect one. A high number of attempts on the Evaluate screen can be interpreted as students having difficulty interpreting their results and evaluating their initial hypothesis.

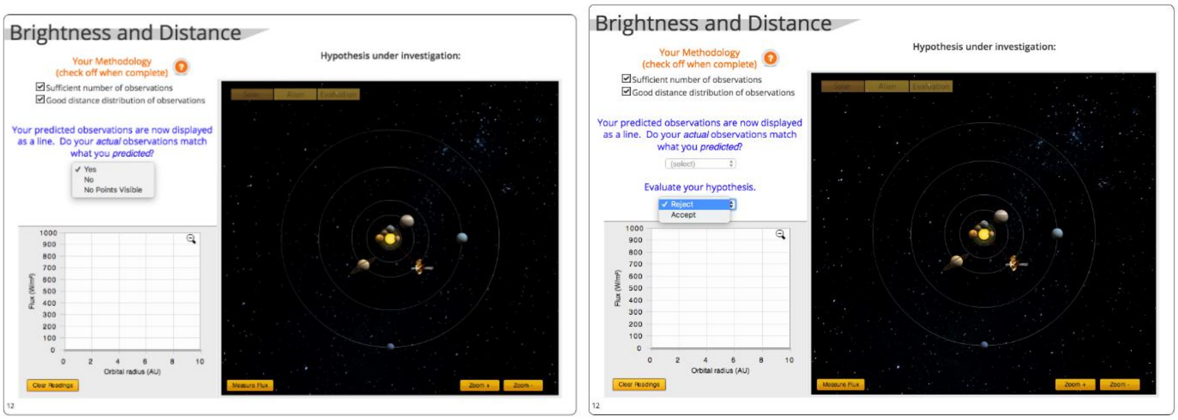

Figure 2: Analysis (left) and Evaluate (right) screens in the R*2 Brightness lesson

After completing the POE tasks in the Brightness lesson, students were invited to complete a questionnaire to report their level of SRL related to monitoring ("While completing this task, I asked myself questions to make sure I understood the material.") and regulating skills ("While completing this task, I tried to change my approach to the task depending on the feedback received."), and their attitude towards task difficulty ("Overall, how challenging was the material in the preceding task?"), and confidence completing the task ("Overall, how confident are you that you understood the material in the preceding task?"). All items were adapted from previous research (see de Barba, Kennedy & Trezise, 2017). Single-item measures were used to minimally disturb students during course activities (de Barba, Kennedy & Ainley, 2016). A 7-point Likert scale was used (1 strongly disagree to 7 strongly agree).

Audit logs collected throughout the Brightness lesson were used to investigate students' interactions with the content. These included time, number of attempts on a screen, students' response and feedback provided (automatically triggered based on students' responses and interaction with screen elements, such as the simulation). Students could attempt a lesson several times, but for the current study we focused on their first lesson attempt to examine their initial interaction with the content.

Results

In order to examine the association between students' SRL and related attitudes with their interactions when completing an online scientific inquiry-based task, we first clustered students based on their reported score for monitoring, regulating, challenge and confidence. A Two-Step clustering method was used. Two clusters were suggested, but three and four cluster solutions were also considered. The two and three cluster solutions had unequal group sizes and did not discriminate among all clustered variables. The four-cluster solution, on the other hand, produced clusters with similar sizes and was able to provide a richer combination of students' SRL measures. Table 1 presents the four student groups that resulted from this analysis.

The four clusters varied on two levels of monitoring and regulating (high or low), two levels of challenge (high or low) and three levels of confidence (high, medium and low). We labeled the two levels of monitoring and regulating as "SRL", the combination of high challenge with low or medium confidence as "Confused" , and the combination of low challenge with high confidence as "Confident". Clusters 1 and 2 reported lower monitoring and regulating values than clusters 3 and 4. The difference between Clusters 1 and 2 was that Cluster 1 reported high challenge and low confidence, while Cluster 2 reported low challenge and high confidence. Similarly, the difference between Clusters 3 and 4 was that Cluster 3 reported high challenge and medium confidence, while Cluster 4 reported low challenge and high confidence.

Table 1: The four SRL groups

	Cluster label	Monitoring	Regulating	Challenge	Confidence
Cluster 1 (n=57)	*Low SRL Confused*	3.47 (1.28) ^{a}	3.77 (1.18) ^{a}	4.14 (1.17) ^{a}	2.96 (1.36) ^{a}
Cluster 2 (n=32)	*Low SRL Confident*	3.16 (1.32) ^{a}	3.63 (1.41) ^{a}	2.31 (0.97) ^{b}	5.78 (0.42) ^{b}
Cluster 3 (n=89)	*High SRL Confused*	4.84 (0.89) ^{b}	5.34 (0.69) ^{b}	4.51 (0.77) ^{a}	4.84 (0.89) ^{c}
Cluster 4 (n=55)	*High SRL Confident*	5.11 (0.71) ^{b}	5.31 (0.69) ^{b}	2.27 (0.73) ^{b}	5.33 (0.70) ^{b}

Notes. Different superscripts indicate significant differences across rows.

Group difference analyses were then conducted to identify cluster differences on students' audit logs from their interaction with the POE-related screens. One MANOVA was conducted for total time spent on each of the screens, and another MANOVA was conducted for number of attempts students made on each of the screens. There was a significant difference between clusters for the number of attempts students made on each screen (F (12, 579) = 2.30, p = .007; Wilk's Lambda = 0.884, partial eta squared = .04), but not on the total time spent on each of these screens (F (12, 579) = 0.90, p = .552; Wilk's Lambda = 0.953, partial eta squared = .02). Specifically, we found differences among groups in the number of attempts on the Observe and Analysis screens. On the Observe screen, students in Cluster 1 (Low SRL, Confused) had more attempts than those in Cluster 4 (High SRL, Confident). On the Analysis screen, students in Cluster 1 (Low SRL, Confused) had more attempts than those in Cluster 2 (Low SRL, Confident).

A Chi-square was conducted to examine students' responses (Correct/Incorrect/Missing) for the Observe, Analysis and Evaluate screens. A significant result was only recorded for the Observe screen, X2 (6, N = 233) = 18.68, p = .005. This showed that students in Cluster 1 (Low SRL, Confused) were more likely to select an incorrect response and less likely to select a correct response.

Considering the results so far indicating that Cluster 1 students (Low SRL, Confused) were finding it difficult to progress in the POE task, we further examined the type of incorrect feedback triggered on their first attempt on the Observe and Analysis screens (Figure 3). On the Observe screen, two types of feedback were triggered related to designing an experiment ("Not enough observation" and "Skewed data"), with "Not enough observations" being the most frequent; while the other two types of feedback were related to not completing the task correctly ("No checklist" and "Same observations"). On the Analysis screen, most of the feedback triggered was related to students accepting an incorrect initial hypothesis.

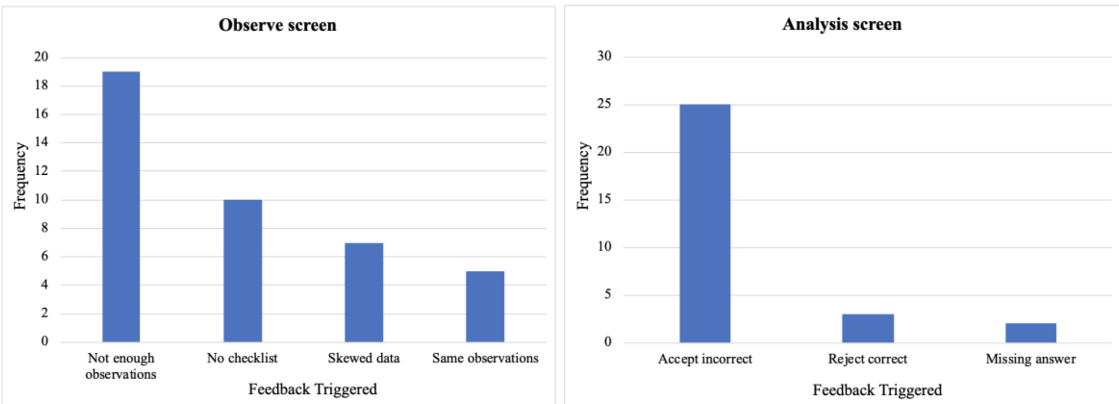

Figure 3: Frequency of feedback types triggered on the Observe (left) and Analysis (right) screens for Cluster 1 students

[5] Reports of high challenge and low confidence have been associated with the state of confusion in learning situations (de Barba, Kennedy & Trezise, 2017).

Discussion and Conclusion

Taken together, findings from the current study suggest that students' SRL together with their attitudes toward learning impact how they completed an online scientific inquiry task. This was reflected in behavioral differences between the groups with different self-reported levels of SRL and attitudes in the POE task. Particularly, we found that students with low self-reported SRL skills and confusion (high challenge and low confidence) presented behaviors related to known difficulties that students face when applying the scientific inquiry process: designing inconclusive experiments and misinterpretation of data.

Designing inconclusive experiments occurs when individuals "do not always behave as logical thinkers and do not perform the actions that would be most effective for testing a hypothesis" (De Jong & Van Joolingen, 1998, p. 185). This difficulty was evident on the Observe screen, where students were asked to conduct an experiment to investigate the relationship between brightness and distance. Students with low self-reported SRL skills and confusion (Cluster 1) made more attempts and obtained more incorrect responses than confident students with high SRL skills (Cluster 4). Further analysis showed that Cluster 1 students' additional attempts and incorrect responses were related to creating too few observations in the simulation. From these findings, we can infer that problems students from Cluster 1 faced in this task were related to their knowledge about the scientific inquiry process (i.e., how many observations would be effective to create an experiment to test the relationship between two variables) rather than the content being learnt (i.e., concepts of brightness and distance). However, due to students in Clusters 1 and 4 differing on both SRL (monitoring and regulating) and attitudes (challenge and confidence), we cannot relate difficulty with designing experiments to any one of these constructs separately.

Misinterpretation of data is when students do not interpret their observations correctly. This is considered a type of confirmation bias, where students' initial hypothesis guides the interpretation of their observations (De Jong & Van Joolingen, 1998). This difficulty was evident on the Analysis screen, where students were asked if their observations matched their initial prediction. Students with low self-reported SRL skills and confusion (Cluster 1) had more attempts than confident students with low SRL skills (Cluster 2). These additional attempts were related to Cluster 1 students accepting their initial incorrect prediction. Considering these groups had similar SRL skills, students' difficulty interpreting data was most likely associated with their perception of task difficulty and confidence. However, it is difficult to determine whether the misinterpretation of data was related to their knowledge of the scientific inquiry process (i.e., being unable to interpret data from graphs in general) or to the content being learnt (e.g., not understanding the relationship between brightness and distance).

In sum, this preliminary study begins to unpack the relationship between specific aspects of SRL and phases of the scientific inquiry process. As the main implication of this type of study is to inform personalised interventions, it is crucial for future studies to (1) better understand the interplay between aspects of SRL and their impact on scientific inquiry learning (i.e., focus on controlling for phases of SRL in relation to students' perceptions of task difficulty and confidence), and (2) carefully consider task design so as to capture distinct learning analytics for learning markers of the scientific inquiry process and of the content knowledge.

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