Procedural and conceptual confusion in a discovery-based digital learning environment

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Confusion has been found beneficial to learning in specific conditions. However, the roles of procedural and conceptual confusion in such conditions are still unknown. This paper presents a preliminary study investigating the relationship between procedural and conceptual confusion and their impact on learning processes and outcomes in a non-challenging online task. Participants completed an online predict-observe-explain task on star lifecycles, which included a star simulation. One group watched a video tutorial on how to use the simulation prior to the task (n=22), while the control group did not (n=22). The tutorial group reported higher confidence and lower challenge in using the simulation compared to the control group. The tutorial group also reported higher confidence towards the concept being learnt than the control group, although no differences were found on concept challenge. However, these differences on conceptual and procedural confidence and challenge did not impact time spent on the simulation, use of self-regulatory skills or learning outcomes. Implications for future studies are discussed.

Keywords: confusion, confidence, challenge, self-regulated learning, online learning

Introduction

Confusion has been found to be both beneficial and detrimental to learning. Students tend to benefit from confusion when they are well-supported through the confusion period, resulting in deep learning (D'Mello, Lehman, Pekrun & Graesser, 2014). However, there is still much to understand about confusion and the most appropriate support to be provided once confusion starts to be detrimental to learning (Arguel, Lockyer, Lipp, Lodge, & Kennedy, 2017; Lehman, D'Mello & Graesser, 2012). This study aims to better understand the relationship between the provision of procedural instructions and two types of confusion – procedural and conceptual – in a digital learning environment.

Confusion is an emotion about cognitive processes, particularly about the feeling of not knowing (Hess, 2003). It is usually experienced in challenging situations, when students are not confident about their learning (Lodge & Kennedy, 2015). Once confused, students need support to have a deep learning experience. This support may come from students' themselves, through the use of self-regulated learning skills, or from the environment. Self-regulated learners plan and monitor their learning, making changes to their study approach if they perceive unsatisfactory progress (Pintrich, 2000). When confused for a sufficient amount of time, students are expected to reflect and control their learning. However, students may lack self-regulated learning skills or may not be motivated to activate them. In these cases, the likely outcome of confusion is boredom or frustration, and external support could be useful in assisting students to overcome their confusion.

Digital learning environments have the potential to provide personalised feedback to assist students in overcoming unproductive confusion. This is a two-step process: first digital learning environments need to identify moments of student confusion when assistance is required, and then the environment needs to provide appropriate support to promote effective learning and engagement (Baker, Rodrigo, D'Mello & Graesser, 2010). Even though research has made significant progress over the last decade on the detection of confusion (Arguel et al., 2017), much still needs to be understood about different types of confusion.

Previous research has found that students may be confused about procedural and conceptual knowledge while completing a non-challenging task in a digital learning environment (Kennedy & Lodge, 2016). Procedural knowledge is "the ability to execute action sequences to solve problems", and conceptual knowledge is "one's mental representation of the principles that govern a domain" (Rittle-Johnson, Fyfe & Loehr, 2016, p.577). Therefore, procedural confusion is related to the feeling of not knowing how to execute a sequence of actions to solve a problem, while conceptual confusion is related to the feeling of not knowing about the principles being studied.

Procedural and conceptual knowledge are thought to share an interactive relationship. For example, in the area of mathematics learning, while procedural and conceptual knowledge have been found to influence each other (Rittle-Johnson, Schneider & Star, 2015), it is also possible for students to experience low procedural knowledge (unsure how to solve a problem) and high conceptual knowledge (understand what the concepts are) – or vice versa. In digital learning environments procedural knowledge might be additionally compromised by the usability of a particular educational technology and its interface (Ardito et al., 2004). For example, a student can have limited knowledge about how to use an interface to create a star in an astronomy simulation, but he or she may have more than adequate knowledge about the concept being learnt (e.g., the physics properties of a star).

In a previous study, participants' reported feeling confused about both procedural knowledge on the use of a simulation and conceptual knowledge on the concept being learnt while completing an online predict-observe-explain task in a discovery-based digital learning environment (Kennedy & Lodge, 2016). The task consisted of using a simulation to create stars and observe their lifespan across time (procedural knowledge) to investigate the relationship between their mass and lifecycle (conceptual knowledge). The current study investigated this further but considered the relationship between procedural and conceptual confusion and the impact this has on learning processes and outcomes. The use of a non-challenging task that all participants easily learn allowed us to isolate the effect of procedural confusion, without needing to account for task difficulty or individual differences in cognitive abilities. More specifically, the study examined whether providing procedural instructions on the use of the simulation (i) reduces procedural confusion, (ii) impacts conceptual confusion, and (iii) impacts learning processes and outcome in a non-challenging task.

Method

Participants and context

Participants were 44 students from a metropolitan university in Australia. There were 32 female and 12 male participants, and they were mostly from second- and third-year undergraduate courses (8 from 1st year, 19 from 2nd year, 12 from 3rd year, and five from other). Ethics committee approval was obtained from the University and all participants provided informed consent. Participants were invited to a computer laboratory to complete an online task – *Stellar Lifecycles* – about the relationship between lifecycle of stars and their mass. Stellar Lifecycles was created in the *SmartSparrow* platform with a predict-observe-explain learning design (White & Gunstone, 1992). This online task is part of the online course *Habitable Worlds* at Arizona State University (Horodyskyj, Mead, Belinson, Buxner, Semken & Anbar, 2018).

Measures

1) Procedural and conceptual confusion

In the current study, confusion was measured in the "Observe" phase of *Stellar Lifecycles*, which is where participants' have reported feeling confused previously (Kennedy & Lodge, 2016). Confusion is a construct that is difficult to measure directly through self-report data (see Arguel et al., 2016) and previous studies have used measures of confidence and challenge as proxies for confusion; as confidence correlates negatively with confusion, while challenge correlates positively with confusion (see Lodge & Kennedy, 2015). Therefore, the current study measured confidence and challenge as indicators of confusion.

Procedural confusion was measured by asking participants "How confident are you on operating the Stellar Lifecycles simulation?" and "How challenging is operating the Stellar Lifecycles simulation?" while conceptual confusion was measured by asking participants "How confident are you that you are understanding the concepts covered in this activity?" and "How challenging are the concepts covered in this activity?". A scale from 1 (*not at all*) to 10 (*very*) was used for all items.

2) Learning processes

Learning processes were measured as time spent using the simulation and use of self-regulated learning skills. Time spent using the simulation was recorded by *SmartSparrow* in seconds. Self-regulated learning skills were measured using two items: one on the use of monitoring strategies ("While completing this activity, I asked myself questions to make sure I understood the material") and one on the use of regulating strategies ("While completing this activity, I tried to change my approach to the activity depending on the feedback received").

Items were adapted from previous research (Pintrich, Smith, Garcia & McKeachie, 1991) and used a scale from 1 (*not at all true of me*) to 10 (*very true of me*).

3) Learning outcomes

There were two measures of learning outcomes. The first measure was a comparison between participants' initial hypothesis selected at the "Prediction" phase and the hypothesis selected at the "Explain" phase. Participants were categorized as "learnt", "already knew", "unsuccessful", or "unlearnt". *Learnt* meant that participants selected an incorrect option at the "Prediction" phase, and the correct option at the "Explain" phase. *Already knew* meant that participants selected the correct option for both "Prediction" and "Explain" phases. *Unsuccessful* meant participants selected the incorrect option for both "Prediction" and "Explain" phases. *Unlearnt* meant that participants selected a correct option at the "Prediction" phase, and the incorrect option on the "Explain" phase. The second measure of learning was a knowledge transfer task, where participants solved a problem that required using information learnt during the Stellar Lifecycle. Participants' answers on the transfer task were compared with their answer on the "Explain" screen and were categorized using the same four categories: "learnt", "already knew", "unsuccessful", or "unlearnt". Participants were asked to provide an open-ended explanation whenever selecting a hypothesis. Two participants from the tutorial group, who selected the correct hypothesis in the "Prediction" phase but mentioned that they were guessing in the open-ended question, were considered as selecting an incorrect hypothesis in the "Prediction" phase. No participants mentioned guessing the hypothesis selected in the "Explain" phase or in the transfer task.

Procedure

Figure 1 shows a visual representation of the procedure. On the "Predict" screen participants were asked to select a hypothesis predicting the relationship between star mass and lifecycle. There were four incorrect options and one correct option. After this screen, participants in the tutorial group were directed to the "Tutorial" screen, where they could watch a video with procedural instructions on how to use the star simulation. After watching the tutorial, they were directed to the "Observe" screen. The control group were directed from the "Predict" screen straight to the "Observe" screen. On the "Observe" screen participants used a simulation to create stars with different masses, observe how long their lifecycle lasted, and report mass and lifespan of three stars. After 60 seconds on this screen a pop-up with the first survey automatically appeared, asking students to complete items on procedural and conceptual confidence and challenge. Automated feedback was provided to participants on the "Observe" screen if they tried to move to the next screen without completing the instructions. After the "Observe" screen participants were invited to complete a second survey, with items measuring their use of self-regulated learning strategies. On the "Explain" screen, participants could see which hypothesis they had selected initially, and were asked to select a hypothesis again. They had the same options as on the "Predict" screen. In the final screen participants were invited to complete a "Transfer Task". The transfer task consisted of a problem-based question where participants had to apply the concepts related to the relationship between star mass and lifecycle learnt during the previous task.

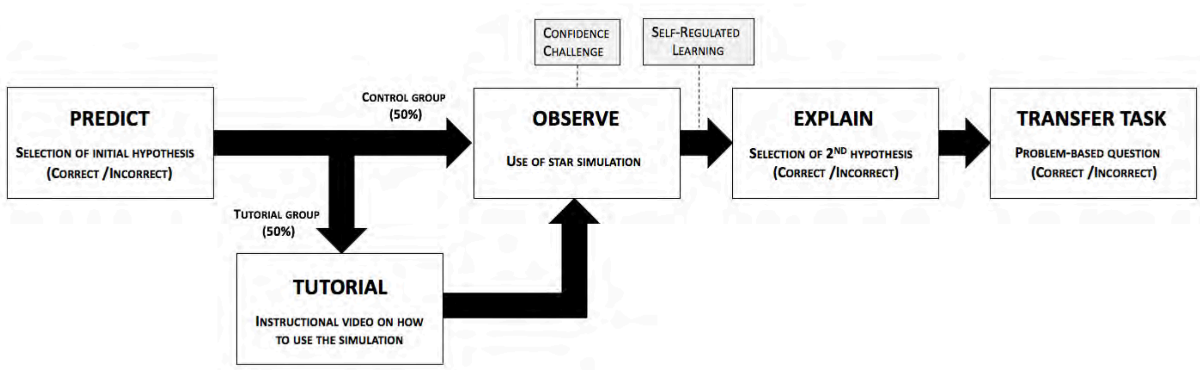

Figure 1: Procedure in the current study.

Results

1) Procedural confusion

A one-way between groups multivariate analysis of variance (MANOVA) was conducted to investigate group differences in procedural confusion. Dependent variables were confidence and challenge towards using the simulation. No violations of normality, linearity, univariate and multivariate outliers were noted. There was a significant difference between control and tutorial group on the combined simulation challenge and confidence variables, F (2, 41) = 11.05, *p* < .001; Wilks' Lambda = .65; partial eta squared = .35. An inspection of the mean scores indicated that the control group reported lower confidence and higher challenge on simulation use than the tutorial group. These results are presented in Table 1.

Table 1: *Group Differences on Simulation Confidence and Challenge*

Variable	Control Group	Tutorial Group	Tests of Between-Subjects Effects
Procedural Confidence	2.97 (2.84)	7.05 (2.85)	F (1, 42) = 22.60, *p* < .001, partial eta squared = .35
Procedural Challenge	6.59 (3.01)	4.26 (3.20)	F (1, 42) = 6.01, *p* = .018, partial eta squared = .13

2) Conceptual confusion

A MANOVA was conducted to investigate group differences in conceptual confusion. Dependent variables were confidence and challenge towards the concept being learnt. No violations of normality, linearity, univariate and multivariate outliers were noted. There was no difference between control and tutorial groups on the combined concept challenge and confidence variables, F (2, 41) = 2.45, *p* = .099; Wilks' Lambda = .89; partial eta squared = .11. However, when considered separately, tests of between-subjects effects found a significant group difference on concept confidence. Mean scores indicated the control group reported lower confidence on the concept being learnt than the tutorial group. These results are presented in Table 2.

Table 2: *Group Differences on Concept Confidence and Challenge*

Variable	Control Group	Tutorial Group	Tests of Between-Subjects Effects
Concept Confidence	3.66 (2.61)	5.52 (3.00)	F (1, 42) = 4.84, *p* = .033, partial eta squared = .10
Concept Challenge	5.99 (2.61)	5.42 (2.33)	F (1, 42) = 0.58, *p* = .450, partial eta squared = .01

3) Learning processes

A MANOVA was conducted to investigate the differences between groups on learning processes. The dependent variables were: monitoring SRL, regulating SRL, and time spent on simulation. No violations of normality and linearity were noted. Time spent on simulation had five outliers, which were not considered in this analysis (three from the control group and two from the tutorial group). There was no statistical difference between control and tutorial groups on the combined variables, F (3, 35) = 0.55, *p* = .649; Wilks' Lambda = .96; partial eta squared = .05. Results are presented in Table 3.

Table 3: *Group Differences on Self-Regulated Learning and Time Spent on Simulation*

Variable	Control Group	Tutorial Group	Tests of Between-Subjects Effects
Monitoring SRL	6.68 (2.89)	6.53 (2.86)	F (1, 37) = 0.03, *p* = .864, partial eta squared = .001
Regulating SRL	6.86 (2.78)	5.98 (2.75)	F (1, 37) = 0.99, *p* = .327, partial eta squared = .03
Time spent on simulation (seconds)	243.47 (84.86)	219.35 (95.18)	F (1, 37) = 0.70, *p* = .410, partial eta squared = .02

Note. SRL = Self-Regulated Learning.

4) Learning outcomes

Chi-square tests indicated that there were no significant group differences on the two measures of learning outcomes: selection of a new hypothesis in the "Explain" screen (X2 (1, n=44) = 4.25, p=.120) and transfer task (X2 (1, n=44) = 5.13, p=.077). Most participants selected the correct answer in the "Explain" screen (43 out of 44) and in the transfer task (40 out of 44).

Discussion and Conclusion

In this study, we investigated the relationship between the provision of instructions and two types of confusion – procedural and conceptual – for a non-challenging task in a discovery-based digital learning environment. The relationship between procedural and conceptual confusion was examined, as well as whether providing procedural instructions impacted on learning processes and outcomes. The results of the study indicated that providing procedural instructions impacted on procedural confusion, with the tutorial group reporting lower challenge and higher confidence towards using the simulation than the control group. Providing procedural instruction, however, did not impact on conceptual confusion. When considering concept and confidence separately, the tutorial group reported higher concept confidence than the control group. In addition, providing procedural instructions did not impact on students' learning processes (time spent using the simulation and monitoring and regulating their learning), or on their learning outcomes.

Participants who watched the instructional video reported higher conceptual confidence than participants who did not watch the video, but that did not impact their learning processes and outcomes. That is, understanding how the content was being presented made them feel confident about what they were learning, but did not make a difference on how they were learning and whether they learnt the content or not. Previous research has reported similar findings, with instructional interventions impacting students' confidence but not their learning outcomes. For example, Carpenter, Mickes, Rahman and Fernandez (2016) found that students who watched videos with higher fluency (strong, deliberate) had more confidence but not better learning outcomes than students who watched disfluent (hesitant, disengaged) videos. This could be partially explained by participants not perceiving the Stellar Lifecycles task as very challenging (i.e., most participants selected the correct hypothesis on the "Explain" phase and on the transfer task). In this case, findings from the current study suggest that there may not be a need to include procedural instruction in low challenge tasks; as providing them did not impact learning processes and outcomes. Future studies investigating the impact of procedural instruction on procedural and conceptual confusion should aim to use a more challenging task – both in procedural and conceptual knowledge.

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