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**The impact of attitudes beliefs and cognitive reflection on the development of
critical thinking skills in online students**

Boban Simonovic^{1*}, Katia Vione¹, Dean Fido¹, Edward Stupple¹
James Martin¹, and Richard Clarke¹,

¹ University of Derby (UK)

* Correspondence concerning this article should be addressed to Dr. Boban Simonovic,
University of Derby, Enterprise Centre, Derby, DE1 3LA, UK. Tel: (01332 597957). E-mail:
b.simonovic1@derby.ac.uk

Abstract

Learning and development of critical thinking skills in higher education is essential for academic achievement. The following experiment is first to examine the effect of online student perceptions and attitudes towards critical thinking across dimensions of confidence, valuing, misconceptions cognitive reflection and authors writing. Furthermore, we developed and examined the effect of four critical thinking workshops with an aim to help students improve their grade point average. Our analyses demonstrated that student's confidence and cognitive reflection predict academic achievement. Moreover, the online CT intervention improved students' CT attitudes, skills, and academic performance. Significant interactions were observed between time (pre and post-intervention) and intervention in cognitive reflection (as measured by the extend version of the cognitive reflection test; CRT) confidence beliefs and attitudes related to critical thinking (as measured by the critical thinking toolkit CriTT), and student grade point average (GPA; as measured by students performance on online modules). It was concluded that the critical thinking can be taught and that an intervention based 'how to think' rather than 'what to think' mixed approach can help students develop critical thinking, strengthen their confidence in critical thinking and help students improve their academic performance in an online setting.

Open data and a preprint of this paper are available at
https://osf.io/3rx5u/?view_only=c16d13c393a74d62bf1c54066552be1c

Key words: Critical thinking, cognitive reflection, critical thinking confidence, teaching, learning.

1. Introduction

Critical thinking is a core skill in higher education and most educators emphasise the importance of fostering students' critical thinking (CT) skills to prepare them for 'real-world' challenges (Facione, 1990; Halpern, 2014; Puig, Blanco-Anaya, Bargiela, & Crujeiras-Perez, 2019). CT skills are considered essential to learning in higher education (Thompson, 2011) not only because they facilitate high academic performance, but because they are associated with higher rates of employability, stronger public engagement, and firm financial position (Facione & Facione, 2001; Osborne, Dunne, & Farrand, 2015). However, although learning and developing CT skills represent an important area of pedagogy, there remains a need for further research in online environment (MacKnight, 2000).

In higher education there is moreover, a goal to develop students who engage in deep rather than surface learning. Deep learning entails a holistic approach whereby understanding is developed via an active learning processes that involves combining concepts and deriving generalisations while weighing evidence and unpacking the logic of the arguments presented in the literature (e.g., Pask, 1988). This further entails the learner engaging in metacognitive processes of monitoring their understanding of the material and their confidence in their responses. Surface learning in contrast, is more likely to entail the rote learning of unconnected facts and a failure to integrate themes or concepts (e.g., Entwistle, 2000). As such deeper learning necessarily requires the ability to think critically about the material in question and is likely to be associated with a greater sense of ownership of the assessment's students write.

Online programmes in higher education are no different from on-campus programmes in terms of promoting CT, and yet unfamiliar teaching techniques in online environment can cause difficulties in about the best methods for fostering CT (MacKnight, 2000). Online discussion boards and text-based communication can help promote CT, however focus is placed on specific, assessment-focused aspects of learning rather than promoting wider CT skills, more generally, which may be transferable to real-life (Maurino, 2007). Furthermore, only limited research exists in online environments, which tests the effectiveness of teaching approaches such as discussion board, focus group, and problem-based and task-based strategies in promoting CT (Guiller, Durndell, & Ross, 2008; Parker, Mayner & Gillham,

2015; Richardson & Ice, 2010). As such, a consensus on how to define, measure, and nurture CT skills through educational effort in online environments is yet to be achieved.

Facione (1990, p 2) defined CT as ‘‘a purposeful, self-regulatory judgment that results in interpretation, analysis, evaluation, and inference as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based’’. This definition captures the multifaced nature of CT and may explain the difficulties that educators face when teaching and promoting CT intervention (Tsui, 2002). Systematic reviews consistently indicate that teaching CT should adopt ‘how to think’ instead of ‘what to think’ approaches to advance teaching strategies that may influence the development of CT skills (Alvarez-Ortiz 2007; Cloete, 2019; Puig et al., 2019). This is particularly important because the teaching of CT skills in higher education has been identified - globally - as an area requiring improvement with students reporting difficulty in understanding and demonstrating CT in their assessments (Abrami et al., 2008; 2015) and many teachers may lack understanding of what CT encompasses and how to teach it (Janssen et al., 2019). For example, Duro, Elander, Maratos, and Aubeeluck (2013) explored students’ and lecturers’ understanding of critical thinking and found a mismatch between students’ understanding of critical thinking and lecturers’ expectations. They recommended structured interactive critical thinking exercises to improve student’s critical evaluation and development of arguments.

Previously, CT has been described as a metacognitive process, believed to be pivotal in logical thinking, decision making, and problem solving (Halpern, 2003). This metacognitive process is associated with the analytic system posited by dual process theorists in cognitive psychology (Bonnefon, 2016; Kahneman, 2011). Dual process theories of thinking and reasoning propose a qualitative contrast between ‘Type 1’ automatic, fast, and implicit processes (e.g., intuitions or gut-feelings) and ‘Type 2’ analytic processes which are conscious, effortful, and self-regulatory. Type 2 processing is associated with executive function and working memory capacity but also other factors that are important in CT such as aptitude for reflective judgments, beliefs and confidence, and propensity to avoid miserly processing of information by relying on Type 1 processes (Toplak, Stanovich, & West,

2014). Thus, we would expect that CT entails cognitive and metacognitive components to enable learning and application of CT skills.

Recent systematic reviews (Abrami et al., 2015; Dwyer, Hogan, & Stewart, 2014; Puig et al., 2019; Ross et al., 2013) have identified a range of measures related to aspects of CT such as dispositions (e.g., the California Critical Thinking Disposition Inventory, CCTDI, Facione et al., 2001), problem solving (e.g., the California Critical Thinking Skills Test, CCTST Facione et al., 1992) and CT-related abilities to process information in a logical manner (e.g., Watson-Glaser Critical Thinking Appraisal, WGCTA, Watson & Glaser, 1964). These measures were widely used to assess students critical thinking, however, there were concerns raised about their psychometric properties as the validity and reliability of these measures is difficult to establish (Abrami et al., 2008; Bernard et al., 2008). Furthermore, these measures do not cover some of the very important elements of CT such as self-regulation (Liu, Frankel, & Roohr, 2014).

The importance of self-regulation and metacognitive thinking was highlighted as an important factor of CT (Dwyer et al., 2014), whereby metacognitive thinking entails self-regulation of thoughts by utilising executive function, such as attention, memory and higher order cognitive skills for application of the CT skills. Dwyer et al.'s framework maps onto dual process theories in terms of the importance of metacognitive processes for thinking, reasoning, and the development of CT skills. As such, engaging in CT requires cognitive reasoning processes, but also metacognitive monitoring where confidence in knowledge and possible strategies are considered and evaluated; as well as metacognitive control processes whereby the thinker determines whether to respond, change strategy or give up on the given task (Ackerman & Thompson, 2017). However, to date only limited research has explored the role of reflective thinking, thinking attitudes, beliefs and confidence in CT behaviour (Cloete, 2019; Janssen et al., 2019; Stupple et al., 2017). Indeed, attitudes to thinking and thinking dispositions have been shown to be important in understanding a range of higher-level thinking and reasoning tasks (e.g., Stanovich & West, 1997). Exploring the aforementioned has the potential to play an important self-regulatory role and may provide a platform for potential interventions aimed at facilitating improvements in critical thinking.

The development of CT depends on cognitive skills and dispositional attitudes that may have an impact on student's ability to develop and demonstrate their CT skills (Ennis, 1985, Facione 2013). For example, Stupple et al. developed the Critical Thinking Toolkit (CriTT) to measure student attitudes and beliefs about critical thinking to predict academic performance. The CriTT significantly correlated with student's ability to over-ride beliefs, the ability to assess arguments strengths and was a highly significant predictor of students' grade point average (GPA). Additionally, CriTT also correlated with cognitive reflection (as measured by the Cognitive Reflection Test (CRT), Frederick, 2005). Furthermore, the CriTT and the CRT predicted a significant and substantial amount of variance in GPA separately. CRT items are designed to measure people's tendency to override their intuitive incorrect response (Type I processes) and to engage in further reflection (Type II processes) that leads to the correct response (Frederick, 2005). Within the dual-process literature, incorrect answers on CRT are explained through individual differences in people's thinking dispositions, their available mindware, and their cognitive ability (Frederick, 2005; Heijltjes et al., 2015; Klaczynski, 2014; West, Toplak, & Stanovich, 2008). People with strong rational thinking disposes people with the tendency to enjoy and engage in effortful thinking and actively open-minded thinking are more inclined to detect the need for a Type 1 override than people with less strong rational thinking dispositions (Stanovich, 2011; Stanovich et al., 2016). Thus, the CriTT and CRT could be used to teach students about common misconceptions about CT and how to challenge those misconceptions by facilitating reflection on their CT and by engaging them in analytic thinking.

Recently, Jansen et al. (2019) examined higher education teachers' performance on an extended version of CRT (Toplak et al., 2014) to test whether CRT performance and teachers thinking dispositions (as measured by Actively Open-minded Thinking scale (AOT; Stanovich & West, 2007) and the Need For Cognition scale – Short Form (NFC; Cacioppo, Petty, & Kao, 1984) affect their attitudes towards teaching CT. Results of a structural equation model showed that a stronger disposition towards effortful thinking, teaching in a more technological domain, and a higher level of education were related to a better CRT performance. Thinking dispositions were also related to teachers' perceived relevance of teaching CT. Confidence in CRT performance rather than actual performance was related to perceived competence in teaching CT. Clearly, CRT represents an important aspect of CT

and warrants further investigation particularly because it was found that it may predict a substantial amount of variance in students' GPA (Stupple et al., 2017).

An idealist view of HE would be for students to engage deeply with the learning and teaching material presented to them, identify with the material, and identify themselves as the authors of their assessments - rather than superficially seeking course credit and passively regurgitating material for grades rather than knowledge. One approach to measuring this variation is through Authorial identity. Authorial identity epitomises the attitudes and beliefs that a writer has of themselves as an author and the way they express themselves in terms of the construct and critical analysis in their writing (Elander, Pittam, Lusher, Fox, & Payne, 2010). Authorial identity is moreover related to the development of CT, particularly in terms of developing writing skills (Cheung, Stupple, & Elander, 2017; Elander et al., 2010). Cheung et al. (2017) demonstrated correlations between beliefs and attitudes about CT and authorial identity suggesting an important link between the development of CT skills and the development of writing skills through education. Indeed, the application of their learned academic literacy is not only essential to the construction of a good argument (Elander et al., 2010) but also may lead to unintentional errors such as plagiarism (Abasi, Akbari, & Graves 2006). Research also indicates that writer attributes may be aspects of authorial identity that students need more help to understand (Abasi et al., 2006; Elander et al., 2010), particularly because the students lack an understanding of what constitutes a good critical evaluation of written work. Thus, examination of students' sense of ownership of written work and authorial ways of thinking may help the development of pedagogic interventions. Furthermore, teaching students about authorial identity may help strengthen their confidence, attitudes and beliefs about their CT skills related to the critical evaluation of the written argument.

Research on the effectiveness of CT interventions indicates that most of the interventions include authentic instruction, mentoring and dialogue and are promoted by Lecture Decision Teaching (LTD), Problem Based Learning (PBL), or a combination of both (Ennis, 2016; Puig et al., 2019). LTD consist of a lecture section followed by a discussion of a specific topic whereas PBL involves dealing with a specific problem that entails finding a solution through research. One aspect of PBL that was emphasised as the most effective is

providing instructions to the students on how to avoid biases in thinking and reasoning (Heijltjes, Van Gog, Leppink, & Paas, 2014, 2015; Van Peppen et al., 2018). However, the lack of transfer of CT across the context and specific tasks suggest that with the immersion approaches (e.g., teaching CT related to the specific subject domain) students struggle to apply CT skills outside of the school context (Puig et al., 2019). Thus, the interventions based on the mixed approaches, where CT is taught separately from the context (general approach) and specific to the context, may be the most effective to students learning. This coincides with Halpern's (2001) argument that to achieve a transfer of CT skills, the students need to acquire CT skills that can be applied to the relevant specific subject but also to many different (e.g., real life) contexts.

We developed four workshops based on the mixed approaches (Ennis, 1989). Our aim was to provide material and guidance for students to first gain some basic understanding about the general CT skills (e.g., Facione, 2001), how to recognize and apply them in real life situations. The second workshop focused on the importance of metacognition (e.g., Stanovich, 2018) and highlighted the importance of 'sharpening' metacognitive skills by thinking of common errors in reasoning and avoiding biases. The third workshops focused on the real-life examples from twitter, fake news and biases, fallacies, and heuristics based on the dual-processes theories (Evans & Stanovich, 2013). The last workshops covered general instructions on how to approach assessments and develop basic strategies when preparing assessment. Thus, our overall goal was to help student become critical thinkers by using 'how to think' rather than 'what to think' approach based on the evidence that teaching strategies that encourage, stimulate, and facilitate students' acquisition and transfer of thinking skills are essential for CT development (Beyer, 2008; Halpern, 1993).

In sum, for students to learn and to apply their CT skills they need to sharpen their metacognitive skills by strengthening their confidence and beliefs in critical thinking and engage in higher order reflective thinking. Furthermore, students need to be aware of possible cognitive biases and errors in reasoning to improve their critical thinking ability. Exploring this further, it has the potential to play an important self-regulatory role and may provide a platform for potential interventions aimed at facilitating improvements in CT. This is the first study to explore the role of CT ability, attitudes and beliefs about CT behaviour and

Authorial Identity, and how they predict both engagement with critical thinking workshops and whether these workshops improve students' critical thinking, change their attitudes and academic outcomes.

Our primary goal was to assess students' critical thinking ability, attitudes and beliefs on critical thinking. The CRT (Toplak et al., 2014) was chosen because it measures analytic thinking which theoretically underpins CT (Halpern, 2014). The CriTT (Stupple et al., 2017) and the SABAS (Cheung et al., 2015) were chosen because they measure attitudes (e.g., aptitudes, beliefs and confidence related to CT and academic writing) that are important in higher education and the development of the critical thinking skills (e.g., Dwyer et al., 2014). Secondly, we assess whether our critical thinking intervention improved critical thinking in students. Grade point average (GPA) was used to examine whether our CT intervention improved GPA and as a direct measure of the correlation between CT and student academic achievement (Facione, Facione, & Giancarlo, 2000). Our workshop design was based on mixed approaches (for a review see Tiruneh, Verburch, & Elen. 2014) whereby the importance of metacognition, real life examples related to cognitive errors and biases, fake news and general assessments preparation were covered. This was to address the complexity and breadth of CT development and help students to communicate effectively their critical thinking.

We predicted that students' attitudes, beliefs and confidence would predict willingness to engage with the workshops. Second, we also predicted that positive attitudes, beliefs, confidence and higher cognitive reflection would positively predict variance in students' GPA. Lastly, we predicted that the students who engaged with the workshops would score higher on CRT, CriTT, SABAS, and GPA after the workshops than students that did not engage.

2. Methods

2.1. Participants

To determine our target sample size, an a priori power analysis using G*Power (version 3.1.9.2) was conducted. Anticipating a medium effect size and a standard alpha level of .05, a minimum of 110 participants would be required to have 95% power in our planned analyses.

We aimed to recruit upwards of 200 participants to account for incidents of missing data and participant withdrawals. A total of 191 university students ($M_{\text{age}} = 38.01$ years, $SD = 8.62$; 62.23 % female) enrolled in an online, British Psychological Society-accredited Master's in Psychology degree at the authors' institution responded to an online advertisement distributed via e-mail lists and module announcements. Inclusion criteria required that participants be fluent in English, aged 18 years or over, and currently studying in an online capacity at the University. Although the workshops were made available to all students, participants reporting current diagnoses of psychiatric, affective, or neurological disorder likely to impact one's ability to learn or critically analyse were asked not to take part in pre- or post-measures. Participants provided written informed consent in accordance with approved university research ethics protocols and British Psychology Society ethical guidelines by ticking a box on both the first and last pages of our online survey.

2.2. Materials.

The Critical Thinking Toolkit (CriTT; Stupple et al., 2017). The CriTT comprises 27 items that measure student perceptions of and attitudes towards critical thinking across dimensions of *confidence*, *valuing*, and *misconceptions* (e.g., "Critical thinking is essential in higher education"), using a 10-point scale. Each item is rated using a scale anchored from "1 - Strongly disagree" to "10 - Strongly Agree" (Cronbach's $\alpha = .899$). For this research, only the total CriTT scores were calculated and analyses; with high scores indicative of greater levels of more positive perceptions of critical thinking.

The Seven-item Cognitive Reflection Test (CRT; Toplak et al., 2014). The CRT comprises 7 items that measure one's ability to resist and override intuitive responses by engaging analytic ability (e.g., "A bat and a ball cost \$1.10 in total. The bat costs a dollar more than the ball. How much does the ball cost?"). Here, one's intuitive response is to state that the ball costs \$0.10 (totalling \$1.20), when the correct answer is \$0.05. Each item is rated using as either correct or incorrect, with higher scores indicative of greater levels of cognitive reflection (Cronbach's $\alpha = .799$).

The Student Attitudes and Beliefs about Authorship Scale (SABAS; Cheung et al., 2017). The SABAS comprises 17 items that measure beliefs and attitudes about academic writing (e.g., “I am able to document my ideas clearly in my writing”) using a 6-point scale anchored from “1 = *Strongly Disagree*” to “6 = *Strongly Agree*” (Cronbach’s $\alpha = .883$). High scores indicated stronger beliefs about and more positive attitudes towards academic writing.

Workshops. Four critical thinking workshops were designed and created by the research team for the purpose of this research using in-built screen capture software for a Macbook Pro (macOS Mojave, v.10.14.6), and were embedded within Qualtrics survey software to monitor compliance and to record responses. Each workshop was approximately 15 minutes in length and focused on the enhancement of critical thinking through: observations, inferences, and assumptions (e.g., Halpern, 2003), fallacies, biases, and heuristics in reasoning and critical thinking (e.g., Kahneman & Tversky 1984; Tversky, & Kahneman, 1983), argument evaluation (e.g., Stanovich, & West 1997), and contrasts in evidence comparison (e.g., Dunn, Halonnen, & Smith, 2008). Workshops combined written and spoken material and asked participants to complete tasks throughout. The survey could not move onto the next section until a task specific amount of time had passed.

2.3. Procedure

On expressing interest to take part in the research, participants accessed the baseline online survey, whereby they entered their demographic information and completed the CriTT, CRT and SABAS. Participants were randomly allocated to either an active (workshop) or waiting-list group, and were e-mailed information on this placement by a researcher ([INITIALS REMOVED FOR REVIEW]), who would remain blind to the subsequent data collection, analysis, and interpretation. Over a four-week period, participants in the active group received weekly workshop materials via email and for completion that week. Each workshop took approximately 15 minutes to complete. Following the final workshop, all participants, were sent a follow-up survey, asking them to complete the CriTT, CRT and SABAS. After completion of the study, links to the workshops were made and debriefing material were provided to all participants. Grade point averages (GPA) were recorded before and after completion of the semester.

2.4. Analytic strategy and scoring

After removing six outliers (because of the extreme values) the data met parametric assumptions. Data were also log transformed (LG10) if they didn't meet normality criteria (e.g., CriTT and SABAS subscales for logistic and multiple regression). Initial analyses focused on checking students' willingness to engage with our workshops by means of logistic regression. Next, a multiple regression with three predictors: the CRT (Toplak et al., 2014); the CriTT (Stuppel et al., 2017) and the SABAS (Cheung et al., 2017) with GPA at the beginning of the semester as the outcome variable. Next, four mixed ANOVA analyses examined the effect of the workshops (before and after semester) and workshops attendance (students attended or did not attend workshops) on GPA, CRT, CriTT, and SABAS. Finally, an independent measures design examined GPA after the semester in three conditions: full workshop completion (N=45); partial workshop completion (N=32) and no workshop completion (N=111).

3. Results

3.1. Regression scores before semester

A logistic regression (Enter method) tested whether CRT, CriTT subscales (Confidence in CT, Valuing CT and Misconceptions), and SABAS subscale (Authorial Confidence, Valuing Writing and Identification with Author) scores predict students' willingness to engage or not engage in our workshops. Overall, 44.2% of the students engaged with workshops. The overall fit of the model is assessed using the log likelihood statistics (Table 1). The model was significant ($p < .001$) and predicted that the low confidence scores in CT (CriTT Confidence) and Authorial Confidence (SABAS subscale) predicted student's engagement with workshops. This indicated that students were likely to engage with workshops because they were lacking confidence in their critical thinking and authorial identity.

Table 1.

Beta and SE, CI and Odds Ratio of Variables Included in Logistic Regression

	B (SE)	Lower	Odds Ratio	Upper	Significance
GPA	-0.02 (0.02)	0.95	0.98	6.22	$p = 0.29$
CRT	0.76 (0.55)	0.73	2.13	1.29	$p = 0.17$

CriTT (Confidence)	-5.61 (0.01)	0.01	0.01	0.19	$p=0.005$
CriTT (Valuing)	1.06 (1.72)	0.09	2.89	8.41	$p=0.54$
CriTT (Misconception)	-0.69 (1.01)	0.07	0.50	3.69	$p=0.50$
SABAS (Authorial Confidence)	-6.58 (1.75)	0.01	0.01	0.04	$p=0.001$
SABAS (Valuing writing)	-1.91 (1.43)	0.09	0.14	3.25	$p=0.18$
SABAS (Identification with Author)	-0.94 (1.08)	0.05	0.39	3.26	$p=0.38$
Notes. $\chi^2=0.10$ (Hosmer & Lemeshow), 0.13 (Cox & Shell), 0.18 (Nagelkerke), Model $\chi^2(8) = 27.55, p = 0.001$					

A multiple regression (Enter method) tested the relative predictive strength of CRT, CriTT subscales (Confidence in CT, Valuing CT and Misconceptions), and SABAS subscale (Authorial Confidence, Valuing Writing and Identification with Author) for GPA baseline scores. After controlling for age and sex, data indicated that the seven predictors combined reliably accounted for 5% of the variability in GPA. The Beta for both CRT and CriTT Confidence scores showed a positive correlation. This indicated that the higher scores on CRT and CriTT Confidence were associated with greater GPA. The remaining variables were not significant predictors of GPA.

Table 2.

Multiple Regression Analysis of Cognitive Reflection Test, Critical Thinking Toolkit and Student Attitudes and Beliefs about Authorship as predictors of student's Grade Point Average.

Predictors	Values
Model 'Enter'	$R^2 = 0.079, R^2_{adj} = 0.049$ $F(7,187) = 2.21, p = 0.03$
CRT scores	$\beta = 4.54, p = 0.03$
CriTT (Confidence)	$\beta = 15.60, p = 0.03$
CriTT (Valuing)	$\beta = 5.37, p = 0.41$
CriTT (Misconception)	$\beta = -3.72, p = 0.35$
SABAS (Authorial Confidence)	$\beta = -5.43, p = 0.35$
SABAS (Valuing writing)	$\beta = 1.81, p = 0.72$

SABAS (Identification with Author)	$\beta = 1.13, p = 0.78$
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Notes. Durbin Watson = 1.93, VIF = 1.019; 1.079; 1.094

3.2. Student's performance before and after semester (with and without workshops attendance)

A Factorial Mixed Measures Design was used to examine the effect of time (before and after semester) and workshops attendance on student GPA. The interaction effect between time and workshops attendance on GPA was also examined.

Data were analysed using a 2 (Time) $\times$ 2 (Workshops attendance) ANOVA. There was a significant main effect of Time $F(1, 56) = 4.35, p = 0.41, \eta_p^2 = 0.07$. Students' GPA was higher before they started the semester than after they completed the semester. The main effect of workshops was not significant $F(1, 56) = 0.21, p = 0.65, \eta_p^2 = 0.004$. However, There was a significant interaction showing that workshop attendance improved after semester scores $F(1, 56) = 58.51, p < 0.001, \eta_p^2 = 0.51$ such that GPA after the semester increased for the students that attended workshops whereas GPA did not increase for the student that did not attend workshops (Table 3).

Table 3.

Student's GPA, CRT, CriTT and SABAS scores (Mean and SD) before and after semester and with or without workshops engagement

	Before semester		After semester	
	No Workshops	Workshops	No Workshops	Workshops
GPA	67.76 (6.59)	61.27 (8.19)	60.67 (8.10)	65.32 (7.69)
CRT	3.33 (1.68)	3.51 (2.17)	3.48 (1.78)	4.73 (2.02)
CRITT	187.28 (26.41)	180.51 (28.26)	177.09 (24.20)	193.95 (32.39)
SABAS	5.21 (0.38)	4.99 (0.58)	5.09 (0.41)	5.21 (0.46)

Next, a Factorial Mixed Measures Design was used to examine the effect of time (before and after semester) and workshops attendance on student CRT scores. The interaction effect between time and workshops attendance on CRT scores was also examined.

Data were analysed using a 2 (Time) $\times$ 2 (Workshops attendance) ANOVA. There was a significant main effect of Time $F(1, 56) = 18.51, p < 0.001, \eta_p^2 = 0.25$. Student's CRT scores were higher after they completed the semester than before they started the semester. The main effect of workshops was not significant $F(1, 56) = 1.93, p = 0.17, \eta_p^2 = 0.03$. However, there was a significant interaction between time and workshop attendance $F(1, 56) = 11.55, p = 0.001, \eta_p^2 = .17$ where CRT scores after the semester increased for the students that attended workshop while CRT scores did not increase for the student that did not attend workshops (Table 3).

Next, a Factorial Mixed Measures Design was used to examine the effect of time (before and after semester) and workshops attendance on student CriTT scores. The interaction effect between time and workshops attendance on CriTTT scores was also examined.

Data were analysed using a 2 (Time) $\times$ 2 (Workshops attendance) ANOVA. The effect of time was not significant $F(1, 56) = 0.19, p = .66, \eta_p^2 = 0.003$. The main effect of workshops was also not significant $F(1, 56) = 0.35, p = 0.55, \eta_p^2 = 0.006$. However, there was a significant interaction between time and workshop attendance $F(1, 56) = 27.51, p = 0.001, \eta_p^2 = .33$ where CRiTT scores after the semester increased for the students that attended workshop while CRT scores did not increase for the student that did not attend workshops (Table 3).

A Factorial Mixed Measures ANOVA examined the effect of time (before and after semester) and workshops attendance on student SABAS scores. Data were analysed using a 2 (Time) $\times$ 2 (Workshops attendance) ANOVA on students SABAS scores – attitudes and beliefs about academic writing. The effect of time was not significant $F(1, 56) = 1.82, p = 0.18, \eta_p^2 = 0.03$. The effect of workshops was also not significant $F(1, 56) = 0.01, p = 0.97, \eta_p^2 < 0.001$. There was no interaction between time and workshop attendance $F(1, 56) = 0.76, p = 0.38, \eta_p^2 = 0.01$.

3.3. Number of workshops completed (post hoc analyses)

A significant minority of students ($N = 32$) engaged in some workshops and we run a post hoc test to check if the effect of students completing only some of the workshops (less than 4) on their GPA after semester. Thus, we used an independent measures design to

examine GPA after the semester in three conditions: students completed all workshops (N = 45); students completed some workshops (N = 32) and students completed none of the workshops (N = 111). The mean number of GPA in each condition is shown in Table 4.

Table 4.

Median GPA (with Interquartile range) by workshops condition

Workshops completed		
All (N = 45)	Some (N = 32)	None (N = 111)
65.00 (12.00)	65.00 (9.75)	58.00 (14.00)

Data were analysed using a Kruskal-Wallis test. There was a significant main effect of workshops condition ($\chi^2(2) = 24.78, p < 0.001$). Post hoc Mann Whitney U test comparison (alpha adjusted to 0.01) indicated higher GPA for students that completed all workshops than no workshops ($U = 1386.00, p < 0.001$), and higher GPA for students that completed some workshops than no workshops ($U = 1066.00, p = 0.001$). However, there was no significant difference in GPA scores for students that completed all or some workshops ($U = 699.50, p = 0.83$).

4. Discussion

The current study replicated previous findings that that CT abilities, attitudes, and confidence predicted students' GPA at baseline level. As predicted, attitudes, beliefs, and confidence related to both CT and academic writing predicted students' willingness to engage with the workshops. Moreover, it was observed that students who engaged with workshops exhibited improved GPA, CT skills, and CT attitudes scores. Results are discussed in detail in the following sections.

Workshop participation and engagement. Scores on attitudes and confidence in critical thinking (CriTT) and academic writing (SABAS) predicted students' participating in the workshops. This suggests that students who were not confident in their CT and academic writing were more likely to take opportunities to further develop their CT skills. The results reinforce the predictive value of the CriTT, especially in terms of identifying students who lack confidence in their CT skills (Stupple et al., 2017). This coincides with evidence that

identifying, challenging, and building stronger confidence in attitudes and beliefs about CT is an important facet for the development of students CT skills (Celuch, Black, & Warthan, 2009). GPA and cognitive reflection (CRT) did not predict willingness to take part in the workshop.

Differences in GPA at baseline. The current findings indicate that attitudes and beliefs towards CT (CriTT) and cognitive reflection (CRT) predicted differences in GPA at baseline. Specifically, it was found that students who are more confident about CT and higher cognitive reflection had achieved higher grades in modules completed before the intervention. These findings confirmed our predictions and give support to previous literature showing that confidence and attitudes towards CT and cognitive reflection predict academic performance (Stupple et al., 2017). This indicates that the development of CT skills depends on dispositional attitudes that have an impact on student's confidence to develop and demonstrate their CT skills (Ennis, 1987). To successfully develop CT interventions, it's not only important to understand how students think and reason, but also what they believe and how they structure their belief system (Lamont, 2020).

In line with previous research our current findings indicate that there is elaborate interplay between CT and cognitive reflection (Kember, Leung, Jones, & Loke, 2000; Kraft, 2002; Kuiper, 2002). Based on our results and previous research, it is plausible to propose that cognitive reflection -- the ability to analyse and critically evaluate information and arguments -- provides students with capability not only to engage in learning strategies but also to utilise executive functions to be more reflective and organised in preparation for their assessments (Dwyer et al., 2014; Phan, 2006). Thus, reflective students are more likely to overcome uncertainties, to critically evaluate their argument and to monitor and self-regulate their thinking. Considering the above, the various versions of CRT currently available are a potent measure of cognitive reflection that can be applied in higher education. The ability to measure the tendency to override initial biases in uncertain conditions and predict variance in students' GPA can be an important tool in understanding aptitude and identifying where to target tailored support for student who most need it (Toplak et al., 2014; Simonovic, Stupple, Gale, & Sheffield, 2018; Stupple et al., 2017).

Intervention (workshop) effects. The most notable contribution of the present study is that the online CT intervention improved students' CT attitudes, skills, and academic performance. Significant interactions were observed between time (pre and post-intervention) and intervention in CRT, CriTT, and GPA. Participants who took part in the workshop improved their scores in these three aspects significantly more than participants who did not take part in the workshop. Where there was a non-significant main effect of intervention, this might be explained by meta-analytic findings suggesting improvements in CT typically vary throughout temporal stages of educational courses (Huber & Kuncel, 2016). However, it remains unclear to what extent any gains are sustainable and so further exploration is required. Nevertheless, an explicit discussion of critical thinking is important, which is one of the strengths of the present study. Abrami et al.'s (2009) meta-analysis with 117 studies indicated that CT interventions with explicit instructions and where it was part of the course objectives had the strongest effects, whereas immersion interventions (when CT content is simply embedded in the course and not part of the objectives) had the lowest effects. The effect of our intervention and post-hoc analysis also indicated that taking part in at least one of the workshops was sufficient to improve GPA. However, our sample was limited to pinpoint the specific workshop that produced the largest effects. Nevertheless, our results are encouraging given the suggestion that even a 15-minute explicit intervention can produce significant effects. Therefore, this can easily be included as part of a programme of learning without adding a significant workload to students.

CT is rewarded in HE and has been consistently a moderate predictor of student achievement, as observed by Fong et al. (2017) in a meta-analysis with 23 studies, which assessed student achievement in different ways (e.g., retention in community college, degree attainment, and course completion or achievement related outcomes such as grades, GPA, or tests). Although some researchers suggest that CT skills might be decreasing in university students (Huber & Kuncel, 2016), our current findings inform that such skills are still relevant for academic achievement and need to be fostered in HE. Even though, the debate whether and how to improve CT skills is still ongoing (e.g., Puig et al., 2019) our results indicate that CT skills can be improved by using a mixed method approach and providing students not only a specific instructions related to the assessments, but also teaching students

‘how to think’ in more general terms about CT and the importance of metacognitive awareness about their thinking.

4.1. Limitations and Future Direction

Limitations of our research, and future directions are as follows. First, participants self-selected to take part in the study which explicitly informed that the workshops might have the potential to improve CT skills. Although a possible bias, this was circumvented as much as logistically possible using a waiting list procedure whereby students in the comparison group also expressed their interest in taking part in the workshop – suggesting equivalent motivation between the two groups (although this was not formally assessed). Second, academic achievement was only measured as a function of GPA. Butler, Pentov, and Bong (2017) suggested that students with higher CT skills also report more positive life events compared to students with lower CT skills. Therefore, future studies should consider the benefits of a CT intervention beyond academic achievement, including real life events. Finally, even though our intervention was designed as a mixed-method approach with an aim of enhancing general CT skill, we note that CT skills may be transferable between contexts; however, the current study considered a short period of time and the intervention lasted four weeks during a 12 weeks term. Thus, we are not sure if the learned skills are transferable and what is the lasting effects of the intervention. Future studies should also address the differences between each 15 minutes workshop to understand the minimal level of instruction for significant effects.

There are further limitations with the use of the CRT. Some items are increasingly well known (e.g., the bat and ball problem), most CRT questions are mathematical and there are some gender differences in performance (Campitelli & Gerrans, 2014). Thus, some caution should be exercised when using variants of the CRT when predicting grades, particularly among maths anxious individuals (Morsanyi, Busdraghi, & Primi, 2014). There are, however, an increasing variety of cognitive reflection tests available that have varying difficulty levels and reduced reliance on mathematical ability (Thomson & Oppenheimer, 2016), and as such, with careful item selection and variation they can provide a useful tool in higher education settings.

5. Conclusion

To our knowledge, this was the first study to examine the effect of an explicit critical intervention with online HE students. Our results indicate that the CT skills can be enhanced with brief online workshop interventions, and that cognitive reflection, attitudes and beliefs may play an important part in the development of students' CT skills both through orienting towards opportunities to develop this skills and academic outcomes. Furthermore, we demonstrated that a short, mixed-method intervention may improve students' GPA. Moreover, even one 15 minutes session of the intervention can be sufficient to improve students' academic performance. Although there are some limitations to our study, our results are encouraging for offering opportunities to students to develop CT skills, additional to modules and class workload.

Declaration of Competing Interests

The author(s) declare no potential competing interests with respect to the research, authorship, and/or publication of this article.

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