Subject Comprehension and Critical Thinking: An Intervention for Subject Comprehension and Critical Thinking in Mixed-Academic-Ability University Students

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ABSTRACT | Subject comprehension and critical thinking are both key goals of higher education. However, while the former is, on the whole, successfully cultivated in undergraduate students, the latter is not. Few empirical studies have investigated the relationship between subject comprehension and critical thinking. In the present article we suggest that supporting the development of subject comprehension is not at odds with developing critical thinking. In fact, we argue that subject comprehension plays a key role in developing critical-thinking skills. Using an experimental design, we demonstrate differing effects of an intervention on subject comprehension, subject-specific critical thinking, and general critical thinking as a function of students' academic background. We discuss the implications of our results for teaching in higher education.

KEYWORDS | intervention, critical thinking, subject comprehension, academic ability

1. Background

The philosopher and psychologist John Dewey (1925, 1933) argued that it was imperative that individuals learn how to apply critical approaches to all aspects of their lives. Critical thinking has been referred to as purposeful reflection and logical reasoning (e.g., Brookfield, 1987; Ennis, 1989; Paul, 1992; Sternberg, 1986), as well as the academic ability to construct and evaluate arguments (e.g., Facione, 1986, 2015; Giancarlo & Facione, 2001; Nickerson, Perkins, & Smith, 1985; Taube, 1997). Although critical thinking takes different forms in different cultures, it is frequently cited as a key objective of higher education

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(American Association of Colleges and Universities, 2005; Australian Council for Educational Research, 2002; Dunne, 2015; Higher Education Academy, 2014). However, academic institutions do not consistently and reliably develop such skills in undergraduate students, with only around 6 percent of university graduates considered proficient (American Association of Colleges and Universities, 2005; Dunne, 2015; Ku, 2009). Employers of recent graduates also echo these concerns (Abrami et al., 2015; Dunne, 2015). Moreover, in the workplace, critical thinking is consistently cited as a key skill above and beyond subject comprehension (Critchley, 2011; Dearing, 1997). In line with this, according to a recent survey conducted by CV-Library (Wilson, 2016), more than half of U.K. graduates are working in an area unrelated to their undergraduate degree.

Therefore, it is important to establish how critical thinking can be supported in university students. In contrast to critical thinking, subject comprehension is often at the core of teaching, with many assessments centered on measuring comprehension of subject knowledge. For example, Momsen, Long, Wyse, and Ebert-May (2010) show that 93 percent of introductory biology courses at a university were assessing knowledge and subject comprehension as opposed to higher-level cognitive skills such as critical thinking.

In the present article we suggest that supporting the development of subject comprehension is not at odds with developing critical thinking. In fact, we argue that subject comprehension plays a key role in developing critical-thinking skills. As our review of literature shows, subject-specific knowledge is a key factor in most critical-thinking scenarios, and techniques that embed critical thinking in a meaningful context for the learner are more likely to improve thinking skills than content-free techniques. Yet few theoretical models and empirical studies have explicitly examined subject comprehension and critical thinking together (Anderson & Krathwohl, 2001; Bloom, 1956; Dwyer, Hogan, & Stewart, 2014; Marzano, 2001; Şendağ & Odabaşı, 2009). This intervention study contributes to our understanding of these abilities by examining subject comprehension alongside critical thinking in a group of mixed-academic-ability university students. Understanding the relationship between subject comprehension and critical thinking will inform models of teaching that encompass this broad range of abilities.

1.1. Literature Review

Critical thinking is a notoriously nebulous concept. Our work is inspired by a number of theoretical frameworks that attempt to account for the constellation of abilities linked to critical thinking. For example, Dwyer et al.'s (2014) framework proposes an interaction between subject comprehension

and critical thinking. Similarly, Bloom's taxonomy of educational objectives characterizes thinking skills into categories ranging from lower-order (knowledge, comprehension) to higher-order thinking skills (which overlap with critical thinking in its modern conception; Bloom, 1956; Moseley et al., 2005; see also Anderson & Krathwohl, 2001). However, the exact nature of the relation between critical thinking, subject comprehension, and other related abilities is still debated (Kreitzer & Madaus, 1994).

Critical thinking is often assessed either at a subject-specific level (i.e., specific to a particular subject) or at a general level (i.e., content-independent; see Ennis, 1989; McPeck, 1990). In line with this, critical-thinking tests can be subject-specific (statistics, biology, psychology, etc.) or general (Lawson, 1999; McMurray, Beisenherz, & Thompson, 1991; Royalty, 1995). Examples of the latter include the Watson-Glaser Critical Thinking Appraisal (Watson & Glaser, 1980) and the Cornell Critical Thinking Test (Ennis & Millman, 1985), which contain test items on local and national topics of interest. Several lines of evidence, based on experimental designs, suggest that subject-specific critical thinking and general critical thinking are in fact distinct abilities that merit consideration in their own right (Burke, Sears, Kraus, & Roberts-Cady, 2014; Renaud & Murray, 2008; Williams, Oliver, & Stockdale, 2004).

First, Burke et al. (2014) found improvements in general critical thinking for philosophy but not psychology students following the same intervention, suggesting that critical thinking differs by subject. Renaud and Murray (2008) show that students in an intervention group using higher-order questions significantly increased their subject-specific critical thinking, but not general critical thinking, compared with students who answered lower-order questions. Again this suggests that subject-specific critical thinking and general critical thinking are separable. Finally, Williams et al. (2004) demonstrated that subject-specific critical thinking was a better predictor of exam performance than general critical thinking.

Further evidence for the notion that subject-specific critical thinking and general critical thinking are dissociable comes from the literature on critical-thinking instruction. Explicit instruction about critical thinking is more likely to promote skills such as analyzing, evaluating, and synthesizing than implicit instruction (Abrami et al., 2008; Abrami et al., 2015). Furthermore when students practice critical thinking in a particular knowledge domain, infused within a particular conceptual context, critical thinking is more likely to improve than when critical thinking is taught abstractly without context (Abrami et al., 2008; Bangert-Drowns & Bankert, 1990; McMillan, 1987).

In sum, there is an important distinction to be made between subject-specific critical-thinking and general critical-thinking skills. Together, the findings also suggest that comprehension of subject knowledge is essential to

progressing critical-thinking skills. Understanding the pathways between subject comprehension, subject-specific critical thinking, and general critical thinking is crucial. Nevertheless, the literature is somewhat piecemeal, in that no study has comprehensively evaluated an intervention for its effects on subject comprehension, subject-specific critical thinking, and general critical thinking together.

1.2. Academic Ability, Subject Comprehension, and Critical Thinking

The relationship between subject comprehension and general critical thinking has often been discussed in the context of students' academic ability (O'Hare & McGuinness, 2015). That is, higher-academic-ability students are able to better engage with critical-thinking processes compared with lower-academic-ability students (O'Hare & McGuinness, 2015; for a meta-analysis in the medical education field, see Ross, Loeffler, Schipper, Vandermeer, & Allan, 2013).

Recognizing individual differences in academic ability has implications for how we teach critical thinking. For example, problem-based learning can be an effective method for developing critical thinking in higher-academic-ability students compared with lower-academic-ability students (Lyle, 1958). Lower-academic-ability students may gain more from subject comprehension–focused approaches (Lyle, 1958). In a more recent study, Williams, Oliver, Allin, Winn, and Booher (2003) found that low-academic-ability students did not show statistically significant improvements in critical thinking following critical-thinking practice and feedback, while high-academic-ability students did improve their critical-thinking skills. Thus, students who are exposed to similar learning interventions may show differences in critical-thinking outcomes based on their prior academic ability.

A wide range of factors have been used to make inferences about students' academic ability, including individual differences in exam scores (O'Hare & McGuinness, 2015), course grades (Williams et al., 2003), noncognitive skills (e.g., self-efficacy), and environmental influences (Lent, Brown, & Larkin, 1984; Pintrich & De Groot, 1990). In particular, university selectivity has been identified as an indicator of a student's academic ability level (Pascarella, 2006). In the present study we used the ranking of our participants' university as a proxy for their prior academic ability.

The present study used an experimental design to test the effects of an intervention on subject comprehension, subject-specific critical thinking, and general critical thinking as a function of students' academic background. We used an embedded approach to teaching critical thinking—namely, critical thinking is taught explicitly within the context of subject knowledge (Abrami et al., 2008; Abrami et al., 2015). In particular, this infused critical-thinking approach used higher-order questions to increase critical thinking. We expected the intervention

group to show greater gains on subject comprehension and critical thinking than the control group. Based on existing research, we expected that subject-specific critical thinking would show greater improvement than general critical thinking. We also expected this effect to vary as a function of prior academic ability.

2. Method

2.1. Participants and University Recruitment

A total of 101 undergraduate political science students were recruited for the study, including fifty-two males and forty-nine females aged between seventeen and thirty-four (mean age nineteen years). The majority of the students who took part in the study were second-year undergraduate students (fifty-three); but participants also included some first-year (thirty-eight) and final-year students (ten). In total fifty-one students took part in the intervention group, thirty-one of whom were male, and fifty students took part in the control group, twenty-one of whom were male. Students were recruited from both single honors and joint honors undergraduate political science degree programs.

The assumption we made in the present study is that university entry requirements act as a good proxy for student academic ability. In line with this, a key target of the recruitment process was to identify a cross section of universities. Using the UK University League Table (Complete University Guide, 2015), we identified universities that were ranked in terms of their entry requirements for political science and grouped the universities into four groups, referred to as university quartiles. University quartile 1 reflected high academic ability (n = 25); university quartile 2, upper-middle academic ability (n = 37); university quartile 3, lower-middle academic ability (n = 17); and university quartile 4, low academic ability (n = 22). In total, eight U.K. universities agreed to take part in the study, with at least one university in each university quartile.

In each university, students were recruited via lecture announcements and e-mail invitations. The students who volunteered to take part in the study were paid £60 payment in return for ten hours of participation, which included seven hours of independent study period and a two-hour test. Prior to taking part in the study all students were prescreened to ensure that prior subject knowledge was not a factor that could influence performance on the subject comprehension and subject-specific critical-thinking tests. In particular, the subject-specific critical-thinking test assessed critical-thinking skills (e.g., analysis, evaluation) in relation to two seminal political texts, Huntington's "The Clash of Civilizations?" (1993) and Fukuyama's *The End of History and the Last Man* (1992). Hence, any students who had read these texts were not eligible to take part in the study. This resulted in twenty-eight students being excluded from the study. None of the eight universities required students to take a mandatory critical-thinking

course; however, all eight participating universities were committed to increasing critical-thinking skills in their undergraduate students.

2.2. Measures

Subject Comprehension Test

We developed the subject comprehension test based on two seminal political texts by Huntington (1993) and Fukuyama (1992). The test included twenty multiple-choice questions, each worth one point, with four response options per question. The questions were designed to assess understanding, explaining, and summarizing. Sample questions included "Why does Huntington think the West and Islam are a particularly conflict-prone pair of civilizations?" and "What is Thymos?" Scores could range from 0 to 20. The subject comprehension test had a Kuder-Richardson (KR-20) reliability estimate of 0.65 for the posttest.

Subject-Specific Critical-Thinking Test

As with the subject comprehension test, we developed the subject-specific critical-thinking test based on the two texts by Huntington (1993) and Fukuyama (1992). The test included twenty-one items, each worth one point, and each item contained two response options. The questions were designed to measure students' recognition of inferences, assumptions, interpretations, and evaluation of arguments. An example of a sample item is "In future, conflict will proceed along civilizational, rather than ideological, lines," and students were asked to decide whether four statements were strong or weak conclusions in relation to this statement. Scores could range from 0 to 21. The subject-specific critical-thinking test had a Kuder-Richardson (KR-20) reliability estimate of 0.60 for the posttest.

General Critical-Thinking Test: The Watson-Glaser Critical Thinking Appraisal

The Watson-Glaser Critical Thinking Appraisal (WGCTA) is a forty-item multiple-choice test measuring five critical-thinking skills: inference, recognition of assumptions, deduction, interpretation, and evaluation of arguments (Watson & Glaser, 1980). The test is a general measure of critical thinking because the items focus on everyday scenarios, and no prior subject knowledge is required. An example of a test item is "Should all young people in the United Kingdom go on to higher education?" Each item is worth one point, and each item contains two or five response options. For analysis purposes the percentile score was used, with a graduate norm group as a comparison. Scores could range from 0 to 100. The WGCTA has good psychometric properties, with a reliability of 0.74 to 0.81 (Gadzella, Stacks, Stephens, & Masten, 2005).

2.3. Procedure

Ethical approval for the study was obtained from the Faculty of Education, University of Cambridge. All students provided informed consent before taking part in the study. All students received a unique participant number to allow us to anonymously track their performance on the different tests. Students were randomly assigned to one of the two conditions prior to the intervention in a between-subjects design.

The intervention took place over a four-week period. At the beginning of the intervention all students attended an in-person session with a researcher to receive their study materials. All students, irrespective of group, received sixteen-page extracts from two seminal political science textbooks to read. Further details of the two groups are provided below.

Intervention Group

The study materials for the intervention group were designed to increase subject comprehension of and critical thinking about the extracts from the political science texts. The materials were designed so that the subject content was infused with critical thinking, and students were required to answer higher-order questions on the topics of the two seminal texts as they read the material. Thus, the key ingredient that constituted the intervention was explicit critical-thinking instruction and higher-order question prompts, both of which were designed to elicit critical thinking by students about the materials.

Control Group

The control group did not receive explicit instruction infused into the relevant topic that they would later be tested on. Instead, they were given minimal exposure to critical-thinking instruction, and the instructions they did receive were not based on critical understanding of the seminal texts. The activities were designed to be as similar as possible to those for the intervention group (although the questions they answered were not higher-order questions but based on recall of material). The study materials were matched to the intervention materials based on a number of variables, including length, presentation format, production quality, and subject discipline (political science).

Study Phases

The study consisted of three phases. Phase 1 was a one-hour face-to-face introduction to the study. During this time, all students were given a set of study materials and excerpts from two seminal texts. Students received their study

materials in groups ranging in size from ten to twenty-five. They were informed that the study was about subject comprehension skills and critical thinking. All students were asked to spend at least seven hours working through the multimedia materials and to attend a test session three weeks later. Phase 2 was the three-week study phase, in which students studied independently with the intervention or control materials. Feedback was solicited from the students via e-mail to ensure that they were studying (average self-reported study time = thirteen hours total). The third and final phase consisted of a two-hour test session. Similar to phase 1, the session was administered to groups of ten to twenty-five students at a time, where students completed the subject comprehension and subject-specific critical-thinking tests using a computer (approximately forty minutes). Following this, students completed the forty-item online version of the WGCTA, which was a forty-minute timed test. Students were allowed to consult their study materials during the test session.

Due to the in-depth nature of the study we incentivized students to do their best by offering a prize draw. Students were informed at the beginning of the study that those who performed in the top 25 percent of the study at each university would be entered into a prize draw to receive an additional voucher for an online retailer. On completion of the study, every student received £60 as payment.

3. Results

3.1. Descriptive Statistics

The mean scores for the subject comprehension, subject-specific critical-thinking, and general critical-thinking tests are provided in Table 1. The descriptive statistics show the mean score for each group (intervention versus control) and each university quartile (1, 2, 3, and 4), as well as the mean scores for the groups as a function of university quartile.

3.2. Subject Comprehension

Next we examined whether intervention group (intervention versus control) and university quartile (1, 2, 3, and 4) affected students' scores on the subject comprehension test. A 2-×-4 between-subject analysis of variance (intervention group, university quartile) showed a significant, though small, effect of group on scores, $F(1, 93) = 5.20$, $p < .05$ ($\text{eta}^2 = 0.05$). Students in the intervention group scored significantly higher than students in the control group (see Table 1). There was also a small, significant effect of university quartile on subject

Table 1 | Descriptive Statistics for Tests

Test and University Quartile	*Intervention Mean (SD)*	*Control Mean (SD)*	*Total Mean (SD)*
Subject Comprehension (/20)			
Quartile 1	13.42 (2.15)	13.00 (2.68)	13.20 (2.40)
Quartile 2	12.05 (3.52)	10.35 (2.87)	11.27 (3.31)
Quartile 3	12.57 (3.65)	10.30 (3.80)	11.24 (3.80)
Quartile 4	11.67 (2.67)	10.10 (3.63)	10.96 (3.17)
Total	12.35 (3.05)	10.98 (3.32)	11.67 (3.24)
Subject-Specific Critical Thinking (/21)			
Quartile 1	15.08 (2.43)	14.92 (2.78)	15.00 (2.57)
Quartile 2	15.20 (2.61)	13.24 (3.75)	14.30 (3.29)
Quartile 3	15.00 (2.38)	13.60 (3.06)	14.18 (2.81)
Quartile 4	14.00 (3.07)	14.10 (3.21)	14.05 (3.06)
Total	14.86 (2.62)	13.92 (3.25)	14.40 (2.97)
General Critical Thinking (/100)			
Quartile 1	50.92 (30.10)	32.85 (26.65)	41.52 (29.24)
Quartile 2	31.55 (31.91)	29.35 (23.84)	30.54 (28.13)
Quartile 3	15.29 (19.67)	12.60 (12.18)	13.71 (15.18)
Quartile 4	15.83 (17.57)	31.90 (21.13)	23.14 (20.50)
Total	30.18 (29.75)	27.42 (22.95)	28.81 (26.50)

comprehension ($F[3, 93] = 2.77$; $p < .05$; $\text{eta}^2 = 0.08$). Post hoc least significant difference tests revealed that students in university quartile 1 had significantly higher subject comprehension scores than students in university quartiles 2, 3, and 4 (all ps $< .05$), as shown by Table 1. No other main effects or interactions were significant for subject comprehension scores (all ps $> .05$).

3.3. Subject-Specific Critical Thinking

We considered whether intervention group and university quartile influenced students' subject-specific critical-thinking skills. A 2-×-4 analysis of variance showed no significant main effect of intervention group ($F[1, 93] = 1.90$; $p > .05$) or university quartile ($F[3, 93] = 0.49$; $p > .05$) on the subject-specific scores

(see Table 1 for means). However, as shown in Figure 1, a visible difference was evident between university quartile 2 and 3 student scores as a function of the intervention group. When only considering students of mid-ranking universities (university quartile 2: upper-middle academic ability; and university quartile 3: lower-middle academic ability), the intervention group showed significantly higher scores in subject-specific critical thinking than students in the control group, although the effect was small ($F[1, 52] = 4.68$; $p < .05$; $\text{eta}^2 = 0.08$).

3.4. General Critical Thinking: The Watson-Glaser Critical Thinking Appraisal

Last, we examined students' scores on the WGCTA. There was no significant effect of intervention group on students' general critical-thinking scores as indexed by the percentile scores ($F[1, 93] = 0.11$; $p > .05$; $\text{eta}^2 = 0.001$). In contrast university quartile was an important factor ($F[3, 93] = 4.56$; $p < .01$; $\text{eta}^2 = 0.13$). Post hoc least significant difference tests showed that students in university quartile 1 had significantly higher scores on the general critical-thinking test than students in university quartiles 3 and 4. Similarly, students in university quartile 2 scored significantly higher than students in university quartile 3 (all ps $< .05$). As shown by Table 1 the mean score for university quartile 4 was higher than the mean score for university quartile 3. This is influenced by an outlier, as one student in the control group of university quartile 4 performed

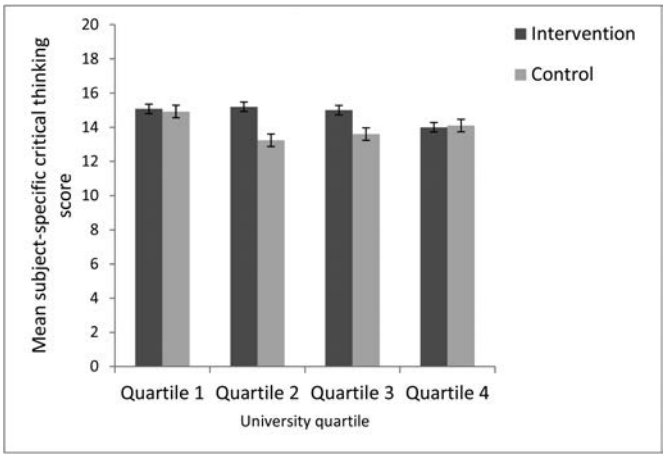

Figure 1 | Subject-specific critical thinking: intervention group and university quartile.

much higher (seventy-second percentile) than the intervention group average (median = nineteenth percentile). The analysis was run with and without this student's data, and this made no difference to the statistical significance of the results.

3.5. Relationship Between Subject Comprehension, Subject-Specific Critical Thinking, and General Critical Thinking

Of particular interest was mapping the relationship between subject comprehension, general critical thinking, and subject-specific critical thinking. To test this, we looked at students who showed significant gains following our intervention, namely, students from university quartiles 2 and 3 (see section 3.3 above). A multiple regression analysis was performed to predict subject-specific critical-thinking scores based on subject comprehension and general critical-thinking scores (overall model: $F[2, 51] = 4.9$; $p = .012$; $R^2 = 0.16$). A t-test revealed that only subject comprehension significantly predicted performance on the subject-specific critical-thinking test ($t[54] = 2.72$; $p < .01$; Figure 2). When subject comprehension increased by 1.00 point, subject-specific critical thinking increased by 0.36 points.

In Figure 2 the subject-specific critical-thinking score (y-axis) is plotted against the subject comprehension score (x-axis), with one data point representing each student's data from university quartiles 2 and 3 only. As indicated by the regression line, there was a positive correlation between the two measures ($r[52] = 0.38$; $p < .01$). This showed that students' subject-specific

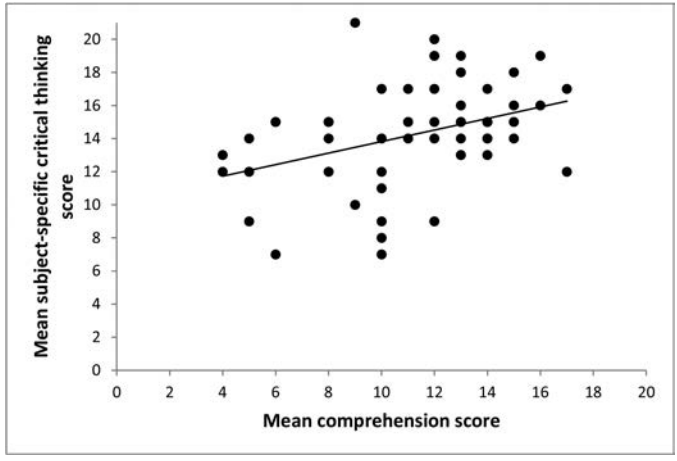

Figure 2 | Subject-specific critical thinking versus general critical thinking.

critical-thinking scores increased as a function of their subject comprehension scores. There were no other significant correlations between scores.

4. Discussion

The present study tested the effectiveness of a critical-thinking intervention on subject comprehension, subject-specific critical thinking, and general critical thinking as a function of students' academic ability. In doing so we examined the relation between subject comprehension, subject-specific critical thinking, and general critical thinking. Our findings are consistent with Dwyer et al.'s (2014) integrated model and the idea that subject comprehension is intimately related to subject-specific critical thinking. Moreover, this study showed that the approach to teaching critical thinking depends on the academic ability of the learners and that not all critical-thinking materials are equally beneficial for all students.

The intervention affected students' subject comprehension, with students in the intervention group scoring significantly higher on the subject comprehension test than students in the control group (consistent with Momsen et al., 2010). Furthermore, students' academic background was an important factor in subject comprehension, with university quartile 1 students showing higher scores compared with students in the other three university quartiles (2, 3, and 4), regardless of intervention group. Our findings show that both the intervention and individual differences in academic background are factors in subject comprehension. We do not believe that our results are due to baseline differences, because students from each university were randomly allocated to either the intervention or the control group.

Only subject-specific critical thinking was improved by the intervention, and this was only the case for students with mid-level academic backgrounds (i.e., from universities in quartiles 2 and 3). This is in line with results confirming that prior academic ability is correlated with critical thinking (O'Hare & McGuinness, 2015; Ross et al., 2013; Williams et al., 2004). Floor and ceiling effects could explain why there was no significant difference for students in university quartiles 1 and 4 in subject-specific critical thinking. Concerning floor effects, one study has demonstrated that students identified as lower academic ability by their course grades did not show significant improvements on a subject-specific psychology critical-thinking test following exposure to a human development course, whereas higher-academic-ability students did show improvements (Williams et al., 2003). It is possible that students demonstrating lower academic ability prefer content-based teaching methods (e.g., lectures) as opposed to problem-based learning (Lyle, 1958), and thus they do not readily engage with critical-thinking programs.

Our intervention used multimedia materials but did not include any instructional support, for example, from a teacher or between peers, throughout the intervention period. It is possible that students from universities that are ranked lower would have benefited from additional scaffolding or motivational techniques to get the most out of the materials (see Azevedo & Hadwin, 2005; Kwan & Wong, 2015). In future, interventions could explore the effects of teacher support, classroom discussions, or online forums on students' developing critical thinking.

Concerning ceiling effects, the lack of a significant effect of the intervention on the subject-specific critical thinking for students in university quartile 1 in the present study might be because students with higher academic ability have less room for improvement. High-performing students tend to adopt study habits that facilitate learning outcomes, and thus it may be that guidance from targeted critical-thinking instruction is not as relevant for these students, because they already have effective learning strategies in place (Williams & Stockdale, 2003).

In contrast to subject-specific critical thinking, we found no effect of the intervention on general critical thinking. This discrepancy is consistent with the existing literature, which suggests that subject-specific critical thinking and general critical thinking are distinct (Burke et al., 2014; Ku, 2009; Renaud & Murray, 2008). This finding is consistent with several studies finding no significant effects of interventions on general critical thinking (Renaud & Murray, 2008; Williams et al., 2004). Insufficient time for the intervention to take effect is often cited as a reason for a lack of significant findings (for reviews, see Abrami et al., 2008; McMillan, 1987). The present study was run over a four-week period. However, some longer critical-thinking interventions, spanning a university term or a year, have also not shown significant differences in students' general critical-thinking academic ability (see McMillan, 1987, for a review). A meta-analysis by Huber and Kuncel (2015) shows stronger effects over time for critical-thinking improvements in university students. But the researchers question whether investing in critical-thinking interventions is worthwhile, given that their meta-analysis shows improvement in critical thinking across the years spent at university, even without explicit intervention. We suggest that future work may usefully include longer-term follow-ups, as some educational research shows effects many years after the initial intervention has concluded (e.g., Marcon, 2002).

Another possibility is that general critical thinking is not as malleable as subject-specific critical thinking. The idea that general critical thinking is more of a trait than a state, and thus less fluid, is receiving greater focus in the literature (Facione, Facione, & Giancarlo, 2000). For example, Facione and colleagues (2000) showed that critical-thinking skills (i.e., cognitive skills) and

critical-thinking dispositions (i.e., more enduring attitudes) are dissociable. They argue that having critical-thinking skills does not necessarily result in critical-thinking dispositions (see also Huber & Kuncel, 2015; Ku, 2009). This implies that education could focus on critical-thinking skills and dispositions as two distinct elements of critical thinking (Facione et al., 2000).

Finally, it is possible that general critical thinking improves more readily than the existing research shows, but that the measures typically used are not sensitive enough to pick up on the improvements. Future research could examine whether changes in general critical thinking are more easily detected with nonstandardized cognitive proxies, such as measures of cognitive flexibility or creative thinking (Cacioppo & Petty, 1982; Gilhooly, Fioratou, Anthony, & Wynn, 2007).

In the present study we assessed students' subject comprehension and general and subject-specific critical-thinking skills, and we were able to triangulate the relationship between these different skills. The findings from our regression analysis show that subject-specific critical thinking correlates with subject comprehension but not general critical thinking. The disconnectedness between subject-specific critical thinking and general critical thinking reinforces the possibility that they draw upon different psychological mechanisms and are thus potentially influenced by different types of interventions and teaching techniques. It also highlights the strong overlap between subject comprehension and subject-specific critical thinking. Another implication is that the particular ways of thinking involved in subject-specific critical thinking may well vary by discipline (see Burke et al., 2014; Hurley, 2011). Further qualitative and quantitative investigations are needed in this area.

Our findings also have important implications in terms of teaching and assessing subject-specific critical thinking at the university level. First, they underscore the importance of approaches to teaching critical thinking. Our findings, alongside previous work, suggest that teaching is effective when it embeds critical thinking in subject content that is related to the test matter (e.g., a so-called infusion approach; Ennis, 1989). Explicitly teaching critical thinking alongside subject content has been shown to be more effective than implicitly teaching critical thinking or teaching critical thinking without subject content (Bensley, Crowe, Bernhardt, Buckner, & Allman, 2010; Bensley & Spero, 2014; Heijltjes, Gog, & Paas, 2014; see also the meta-analysis in Abrami et al., 2008). Higbee (2003) argues that we need to be more explicit about supporting the "habits of the mind" students develop at university, by sharing with them the objectives that subtend our teaching practices. Hence, educators in each discipline may wish to consider which aspects of critical thinking are most relevant to target depending on the discipline at hand.

Another important implication is that student academic ability is a key factor to consider when teaching subject comprehension and critical-thinking skills in higher education. In our study we used university ranking as a proxy for student academic ability. High-academic-ability students typically attend highly selective universities, and low-academic-ability students attend less selective universities. Conversely, the selectivity of the university may also influence the type of teaching experiences a student has, creating a bidirectional relationship between student academic ability and student experience. Tsui (2001, 2003) notes that less selective universities may make pedagogical choices that are less associated with critical-thinking learning outcomes (i.e., no critical-thinking training) compared with highly selective universities where critical thinking is a key focus. Yet critical thinking reflects a set of higher-order thinking skills that are essential for citizenship in the twenty-first century (Abrami et al., 2015; Dewey, 1925, 1933). Considering the extent to which the world is changing and developing, educators should support individuals to learn to think critically so that they can use information flexibly and apply it to novel problems and situations.

At the risk of stating the obvious, in the workplace, managers should ascertain first that basic subject comprehension is in place before requiring critical evaluation of material. Furthermore, given that subject-specific critical thinking seems to be dissociable from general critical thinking, it may be worth putting in place on-the-job development programs that go beyond general management textbooks, to explicitly train employees in the critical-thinking skills most relevant to their profession (Errington & Bubna-Litic, 2015).

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WORKS CITED

Abrami, P. C., Bernard, R. M., Borokhovski, E., Waddington, D. I., Wade, C. A., & Persson, T. (2015). Strategies for teaching students to think critically: A meta-analysis. *Review of Educational Research*, *85*, 275–314.

Abrami, P. C., Bernard, R. M., Borokhovski, E., Wade, A., Surkes, M. A., Tamim, R., & Zhang, D. (2008). Instructional interventions affecting critical thinking skills and dispositions: A stage 1 meta-analysis. *Review of Educational Research*, *78*, 1102–34.

American Association of Colleges and Universities. (2005). *Liberal education outcomes: A preliminary report on student achievement in college*. Washington, D.C.: Author.

Anderson, L. W., & Krathwohl, D. R. (2001). *A taxonomy for learning teaching and assessing: A revision of Bloom's taxonomy of educational objectives*. New York: Addison-Wesley.

Australian Council for Educational Research. (2002). *Graduate skills assessment*. Commonwealth of Australia.

Azevedo, R., & Hadwin, A. F. (2005). Scaffolding self-regulated learning and metacognition–Implications for the design of computer-based scaffolds. *Instructional Science*, *33*, 367–79.

Bangert-Drowns, R. L., & Bankert, E. (1990). *Meta-analysis of effects of explicit instruction for critical thinking*. Paper presented at the annual meeting of the American Educational Research Association, Boston. (ERIC Document Reproduction Service No. ED 328614.)

Bensley, D. A., Crowe, D. S., Bernhardt, P., Buckner, C., & Allman, A. L. (2010). Teaching and assessing critical thinking skills for argument analysis in psychology. *Teaching of Psychology*, *37*, 91–96.

Bensley, D. A., & Spero, R. A. (2014). Improving critical thinking skills and metacognitive monitoring through direct infusion. *Thinking Skills and Creativity*, *12*, 55–68.

Bloom, B. S. (1956). *Taxonomy of educational objectives: Cognitive domain*. New York: McKay.

Brookfield, S. (1987). *Developing critical thinking*. Milton Keynes, U.K.: SRHE and Open University Press.

Burke, B. L., Sears, S. R., Kraus, S., & Roberts-Cady, S. (2014). Critical analysis: A comparison of critical thinking changes in psychology and philosophy classes. *Teaching of Psychology*, *41*, 28–36.

Cacioppo, J. T., & Petty, R. E. (1982). The need for cognition. *Journal of Personality and Social Psychology*, *42*, 116–31.

Complete University Guide. (2015). University subject tables 2015. Retrieved from http://www.thecompleteuniversityguide.co.uk/league-tables/rankings?s=Politics&y=2015.

Critchley, B. (2011). Critical thinking in business education. *Investigations in University Teaching and Learning*, *7*, 5–15.

Dearing, R. (1997). *The Dearing report*. (National Committee of Enquiry into Higher Education.) London: HMSO.

Dewey, J. (1925). *Experience and nature*. Chicago: Open Court.

Dewey, J. (1933). *How we think*. Boston: Heath.

Dunne, G. (2015). Beyond critical thinking to critical being: Criticality in higher education and life. *International Journal of Educational Research*, *71*, 86–99.

Dwyer, C. P., Hogan, M. J., & Stewart, I. (2014). An integrated critical thinking framework for the 21st century. *Thinking Skills and Creativity*, *12*, 43–52.

Ennis, R. H. (1989). Critical thinking and subject specificity: Clarification and needed research. *Educational Researcher*, *18*, 4–10.

Ennis, R. H., & Millman, J. (1985). *Cornell tests of critical thinking*. Pacific Grove, Calif.: Midwest.

Errington, A., & Bubna-Litic, D. (2015). Management by textbook: The role of textbooks in developing critical thinking. *Journal of Management Education*, *39*, 774–800.

Facione, P. A. (1986). Testing college-level critical thinking. *Liberal Education*, *72*, 221–31.

Facione, P. A. (2015). *Critical thinking: What it is and why it counts*. Millbrae, Calif.: Insight Assessment, California Academic Press. Retrieved December 11, 2016, from http://www.insightassessment.com/pdf_files/DEXadobe.PDF.

Facione, P. A., Facione, N. C., & Giancarlo, C. A. (2000). The disposition toward critical thinking: Its character, measurement, and relationship to critical thinking skill. *Informal Logic*, *20*, 61–84.

Fukuyama, F. (1992). *The end of history and the last man*. New York: W. W. Norton.

Gadzella, B. M., Stacks, J., Stephens, R. C., & Masten, W. G. (2005). Watson-Glaser Critical Thinking Appraisal, Form-S for education majors. *Journal of Instructional Psychology*, *32*, 9–13.

Giancarlo, C. A., & Facione, P. A. (2001). A look across four years at the disposition toward critical thinking among undergraduate students. *Journal of General Education*, *50*, 29–55.

Gilhooly, K. J., Fioratou, E., Anthony, S. H., & Wynn, V. (2007). Divergent thinking: Strategies and executive involvement in generating novel uses for familiar objects. *British Journal of Psychology*, *98*, 611–25.

Heijltjes, A., Gog, T., & Paas, F. (2014). Improving students' critical thinking: Empirical support for explicit instructions combined with practice. *Applied Cognitive Psychology*, *28*, 518–30.

Higbee, J. L. (2003). Critical thinking and college success. *Research and Teaching in Developmental Education*, *20*, 77–82.

Higher Education Academy. (2014). *Critical thinking*. Retrieved December 11, 2016, from https://www.heacademy.ac.uk/resources/detail/internationalisation/ISL_Critical_Thinking.

Huber, C. R., & Kuncel, N. R. (2015). Does college teach critical thinking? A meta-analysis. *Review of Educational Research*, *86*, 431–68.

Huntington, S. (1993). The clash of civilizations? *Foreign Affairs*, *72*, 22–49.

Hurley, P. J. (2011). *A concise introduction to logic* (11th ed.). Independence, Ky.: Cengage.

Kreitzer, A. E., & Madaus, G. F. (1994). Empirical investigations of the hierarchical structure of the taxonomy. In W. Anderson & L. A. Sosniak (Eds.), *Bloom's taxonomy: A forty-year retrospective* (pp. 64–81). Chicago: University of Chicago Press.

Ku, K. Y. (2009). Assessing students' critical thinking performance: Urging for measurements using multi-response format. *Thinking Skills and Creativity*, *4*, 70–76.

Kwan, Y. W., & Wong, A. F. (2015). Effects of the constructivist learning environment on students' critical thinking ability: Cognitive and motivational variables as mediators. *International Journal of Educational Research*, *70*, 68–79.

Lawson, T. J. (1999). Assessing psychological critical thinking as a learning outcome for psychology majors. *Teaching of Psychology*, *26*, 207–9.

Lent, R. W., Brown, S. D., & Larkin, K. C. (1984). Relation of self-efficacy expectations to academic achievement and persistence. *Journal of Counseling Psychology*, *31*, 356–62.

Lyle, E. (1958). An exploration in the teaching of critical thinking in general psychology. *Journal of Educational Research*, *52*, 129–33.

Marcon, R. A. (2002). Moving up the grades: Relationship between preschool model and later school success. *Early Childhood Research and Practice*, *4*, 2–24.

Marzano, R. J. (2001). *Designing a new taxonomy of educational objectives*. Thousand Oaks: Corwin Press.

McMillan, J. H. (1987). Enhancing college students' critical thinking: A review of studies. *Research in Higher Education*, *26*, 3–27.

McMurray, M. A., Beisenherz, P., & Thompson, B. (1991). Reliability and concurrent validity of a measure of critical thinking skills in biology. *Journal of Research in Science Teaching*, *28*, 183–91.

McPeck, J. E. (1990). Critical thinking and subject specificity: A reply to Ennis. *Educational Researcher*, *19*, 10–12.

Momsen, J. L., Long, T. M., Wyse, S. A., & Ebert-May, D. (2010). Just the facts? Introductory undergraduate biology courses focus on low-level cognitive skills. *CBE–Life Sciences Education*, *9*, 435–40.

Moseley, D., Baumfield, V., Elliott, J., Gregson, M., Higgins, S., Miller, J., & Newton, D. (2005). *Frameworks for thinking: A handbook for teaching and learning*. Cambridge: Cambridge University Press.

Nickerson, R. S., Perkins, D. N., & Smith, E. (1985). *The teaching of thinking*. Hillsdale, N.J.: Erlbaum.

O'Hare, L., & McGuinness, C. (2015). The validity of critical thinking tests for predicting degree performance: A longitudinal study. *International Journal of Educational Research*, *72*, 162–72.

Pascarella, E. T. (2006). How college affects students: Ten directions for future research. *Journal of College Student Development*, *47*, 508–20.

Paul, R. (1992). Critical thinking: What, why, and how. *New Directions for Community Colleges*, *77*, 3–24.

Pintrich, P. R., & De Groot, E. V. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology*, *82*, 33–40.

Renaud, R. D., & Murray, H. G. (2008). A comparison of a subject-specific and a general measure of critical thinking. *Thinking Skills and Creativity*, *3*, 85–93.

Ross, D., Loeffler, K., Schipper, S., Vandermeer, B., & Allan, G. M. (2013). Do scores on three commonly used measures of critical thinking correlate with academic success of health professions trainees? A systematic review and meta-analysis. *Academic Medicine*, *88*, 724–34.

Royalty, J. (1995). Evaluating knowledge-based statistical reasoning. *Psychological Reports*, *77*, 1323–27.

Şendağ, S., & Odabaşı, H. F. (2009). Effects of an online problem based learning course on content knowledge acquisition and critical thinking skills. *Computers and Education*, *53*, 132–41.

Sternberg, R. J. (1986). Critical thinking: Its nature, measurement, and improvement. In F. R. Link (Ed.), *Essays on the intellect* (pp. 45–65). Alexandria, Va.: Association for Supervision and Curriculum Development.

Taube, K. T. (1997). Critical thinking ability and disposition as factors of performance on a written critical thinking test. *Journal of General Education*, *46*, 129–64.

Tsui, L. (2001). Faculty attitudes and the development of students' critical thinking. *Journal of General Education*, *50*, 1–28.

Tsui, L. (2003). Reproducing social inequalities through higher education: Critical thinking as valued capital. *Journal of Negro Education*, *72*, 318–32.

Watson, G., & Glaser, E. M. (1980). *Watson-Glaser Critical Thinking Appraisal*. San Antonio: PsychCorp.

Williams, R. L., Oliver, R., Allin, J. L., Winn, B., & Booher, C. S. (2003). Psychological critical thinking as a course predictor and outcome variable. *Teaching of Psychology*, *30*, 220–23.

Williams, R. L., Oliver, R., & Stockdale, S. L. (2004). Psychological versus generic critical thinking as predictors and outcome measures in a large undergraduate human development course. *Journal of General Education*, *53*, 37–58.

Williams, R. L., & Stockdale, S. L. (2003). High-performing students with low critical thinking skills. *Journal of General Education*, *52*, 199–225.

Wilson, R. (2016, September 19). Over half of UK workers not using their degree education in working career. Recruitment International. Retrieved December 11, 2016, from https://www.recruitment-international.co.uk/blog/2016/09/over-half-of-uk-workers-not-using-their-degree-education-in-working-career.