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CULTURAL AND REGIONAL PERSPECTIVES

Computer-aided argument mapping in an EFL setting: does technology precede traditional paper and pencil approach in developing critical thinking?

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Abstract Developing higher-order critical thinking skills as one of the central objectives of education has been recently facilitated via software packages. Whereas one such technology as computer-aided argument mapping is reported to enhance levels of critical thinking (van Gelder 2001), its application as a pedagogical tool in English as a Foreign Language (EFL) settings has been rarely explored. In addition, the literature fails to acknowledge whether having the basic skill of representing an argument diagrammatically even with paper and pencil can lead to similar results. That being the case, this study was conducted with the aim of comparing the impact of teaching argument mapping via *Rationale*™ software versus *paper and pencil* on Iranian EFL majors' critical thinking skills development. To this end, 180 EFL participants were screened into low and high levels of reading proficiency based on their scores on a sample reading proficiency test. Next, they were randomly assigned to two experimental and one comparison groups. During 12 sessions, the experimental groups were provided with argument mapping instructions while the comparison group received a conventional reading instruction. All participants were pre- and post-tested with the California critical thinking skills test (CCTST). Results suggested that students in the software group significantly outperformed those in the paper and pencil group on overall CCTST and the sub-skills of inference and inductive reasoning. They also scored significantly higher on all tests compared to the comparison group. However, participants' level of proficiency as well as sex did not show any significant effect on their performance on overall CCTST and its sub-skills.

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Introduction

The beginning of the twentieth century has witnessed the centrality of critical thinking to higher education as a learner's desirable quality (Davies 2011). Today, few would disagree about the importance of integrating critical thinking into all aspects of education including foreign language classes (Stroupe 2006; Synder and Synder 2008). The findings of empirical research in English as a Foreign Language (EFL) settings have also indicated that gearing up students for critical thinking would bring about rewarding outcomes (Chapple and Curtis 2000; Enayat et al. 2015). In the context of teaching reading and writing, for instance, the use of provocative and inferential questions to improve EFL students' critical thinking skills has been suggested (Rezaei et al. 2011). Similarly, to help learners make purposeful judgments, it is assumed that education should produce graduates who are willing and able to use their cognitive powers of analysis, interpretation, inference, evaluation, explanation, and self-monitoring meta-cognition (Ennis 1985; Kuhn et al. 2004; Paul 1984). This is feasible via active deliberate engagement in critical thinking exercises through argument mapping, which provides students with the chance of becoming better critical thinkers. Mapping out reasoning through the use of argument maps can allow students to step back and reflect on their reasoning, identify important issues and assumptions, and more easily clarify their insights (van Gelder 2005).

However, most EFL college students have not fostered adequate levels of critical thinking due to lack of training (Barnawi 2011; Liaw 2007). In her essay on the importance of critical thinking to the community college mission in the U. S., Elder (2000) contends that traditional education does not help students develop the intellectual capabilities needed for personal and academic success in the rapidly changing economic world. That is because students are merely requested to provide facts rather than question or reflect on their reading and construction of personal understandings, and, as a result, they are incapable of drawing inferences.

A similar situation exists in Iranian EFL contexts where, being centralized, schooling consists of k-12 education and higher education. Although western-style higher education in Iran dates back to 1851, it was remodeled by the Supreme Council of the Cultural Revolution following the 1979 Revolution. From then on, the universities in Iran were generally classified into state and private. Aban University, where the present study was conducted, is a state distance-education university which is financially supported by the national budget and students tuition fees. Aban University writes and produces self-instructional course materials and books.

Even though the flourishing literature on critical thinking in an Iranian EFL contexts indicates that it is highly correlated with EFL learners' achievements (Fahim and Ahmadi 2012; Fahim and Mirzaiee 2013; Mall-Amiri and Ahmadi 2014), critical thinking skills have not yet been incorporated into the EFL curriculum of Aban University and even other state and private universities' in Iran which offer EFL programs. Nor is it considered as a major educational goal partly because it is not supported by the content of the EFL textbooks currently being taught in Iranian universities (Azizi 2012). In fact, evidence from these books reveals that emphasis is put more on lower order thinking skills than higher

order ones (Atai and Mazlum 2013; Azizi 2012). Nonetheless, this does not mean that an Iranian EFL context does not include any degree of critical thinking since critical thinking tasks are evident in Iranian culture in much the same way as many other cultures (Evers 2007). The reason might be that in an Iranian context most students prefer intuitive reasoning to formal reasoning compared to the contexts where there is a pedagogical emphasis on critical thinking (Lun et al. 2010, cited in Enayat et al. 2015). As Nisbett et al. (2001) assert, critical thinking "is not something homogenous: there are different ways or forms of reasoning, and they are adaptive strategies in response to particular problems in human life" (p. 400).

As such, Fahim and Ahmadian (2012) claim that "critical thinkers in Iran are not formally and officially trained to be critical thinkers, and critical thinking is in fact a style whose status varies from person to person depending on the training learners received from various teachers" (p. 798). Relying on Bloom's taxonomy of educational objectives as well as the works of Anderson and Krathwohl (2001), Facione (1990a), Marzano (2001), and Romiszowski (1981), the present study explores the effect of argument mapping instruction on EFL learners' critical thinking skills development. In an attempt to contribute to the literature, it also compares computer-aided argument mapping (CAAM) with a paper and pencil method of argument mapping in an EFL context.

Literature review

As a metacognitive process, critical thinking has been conceptualized in various ways. It is simply defined as "the art of being right" by Van Gelder (2001, p. 539). Ennis (1985) defines it as a "reasonable reflective thinking that is focused on deciding what to believe and do" (p. 45). However, the most comprehensive definition is provided by a panel of 46 experts in the U.S. (known as the Delphi report) which describe it as "purposeful, self-regulatory judgment which 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" (Facione 1990a, p. 3; Utah and Waters 2014, p. 144). This report also distinguishes the skills of analysis, evaluation, and inference as the core skills of critical thinking.

Developing critical thinking skills is believed to be dependent on explicit pedagogical approaches (Abrami et al. 2008; Case 2005; Facione 1990a). Referring to the meta-analysis of 117 studies on critical thinking instruction, Abrami et al. (2008) found that critical thinking should be explicitly taught and it would be better to incorporate or infuse it into regular academic content. As such, mixed and infusion approaches suggested by Ennis (1989) are considered the most helpful methods for incorporating critical thinking into the subject matter instruction (Abrami et al. 2008). Similarly, Solon (2007) argues that the infusion of critical thinking into course content, which requires a moderate amount of in-class instruction of materials and exercises, helps learners improve their critical thinking ability. Ramsay (2009) also refers to the usefulness of infusing critical thinking into reading and writing courses across disciplines.

In addition, research findings have revealed that practicing argumentation is strictly tied to the development of critical thinking skills (Alvarez-Ortiz 2007; Kuhn et al. 2004, Twardy 2004). As Johnson (1992) asserts, "critical thinking depends crucially on the capacity of the reflective agent to engage in the practice of argumentation" (p. 71). An argument, on the basis of Toulmin's (1985) model of argumentation, consists of claim, data

which supports the claim, warrants that link the data and the claim, backings that support warrant, and rebuttals which refer to the conditions in which the claim would not be true (Simon 2008).

Notably, information is normally presented in prose which is considered as "the medium of philosophical argumentation" (van Gelder 2002, p. 85). Regarding argumentative prose, i.e., the most common type of genre (Wu 2006), more often students fail to locate the logical structure behind the prose since different interpretations exist and also extracting such a structure from the chain of linear reasoning is a demanding task (van Gelder 2003). This problem can make critical thinking instruction a major challenge to university students (Dwyer et al. 2011). Accordingly, it was suggested that information should be presented in a way that promotes learning by extracting the claims and propositions in a map or diagram (Chandler and Sweller 1991; Pollock et al. 2002). A diagramming strategy called argument mapping was then introduced and used to depict the reasoning and logical relations among the propositions of a given argument (Reed et al. 2007).

As a pedagogical tool, argument mapping augments the chance of meaningful learning as opposed to rote learning (Davies 2010). Having its roots in informal logic, it depicts the strength of each claim in terms of the strength of its premises, and as Blair and Johnson (1987) suggest, in terms of the three criteria of relevance, sufficiency, and acceptability of propositions. Drawing on theories of visual and diagrammatic reasoning (Gurr 1998), argument mapping follows a specific set of conventions using a 'box and arrow' design in which boxes indicate propositions (including central claim or contention, reasons, objections, and rebuttals) and the arrows connecting the propositions show the evidential relations among them (van Gelder 2002). Among the models of diagramming argumentation, Toulmin's (1958) model offered a graphical template for depicting the nature of everyday reasoning (cited in van Gelder 2003). Due to the simplicity of his strategy for diagramming arguments, argument mapping started to appear in textbooks and classrooms, particularly for the purpose of training critical thinking and informal logic (Fisher 1988; van Gelder 2003).

In addition to traditional methods of constructing argument maps, such as paper and pencil, boards, and slides, CAAM has been recently introduced as a learning strategy for argument development (van Gelder 2000; 2007). CAAM provides students with the opportunity to extensively practice reasoning and critical thinking via exercises of increasing complexity, thereby developing expertise in such skills. Furthermore, the argument maps can be easily constructed "in a way that is both scaffolded and guided" (Butchart et al. 2009, p. 271). An argument mapping software, *Rationale*™ (van Gelder 2007), facilitates the construction of argument maps by providing a user-friendly work space and a building panel. There are levels of reasoning boxes which assist a user to construct a map by typing the text into the boxes and then dragging them to their appropriate position on the map. The boxes can be added, removed, edited, or moved to a new location.

The findings of most of the studies conducted in the field of CAAM are promising, suggesting a positive correlation between argument mapping training and critical thinking development (e.g., Butchart et al. 2009; Donohue et al. 2002; Dwyer et al. 2010; Harrell 2011; van Gelder 2001; van Gelder et al. 2004). Dwyer, et al. (2011) compared the impact of training critical thinking via argument mapping with a hierarchical outlining (i.e., a method of extracting themes from a text and then organizing them in a hierarchical way) group as well as a no-instruction control group on measures of critical thinking ability. The participants included 81 freshmen (57 females and 24 males), within the age range of

18–25 years old, who studied psychology at the National University of Ireland, Galway. They were pre-and post-tested with form B and form 2000 of CCTST respectively. Results indicated that whereas there was no significant effect of argument mapping training on overall critical thinking performance, the argument map group outperformed the control group on tests of evaluation and inductive reasoning. Moreover, the outlining group scored higher than the control group on tests of analysis and inductive reasoning. However, as Harrell (2008) suggests, the positive effect of argument mapping via software on critical thinking may be as a result of the computer tutorial environment than the intervention applied. Harrell (2008) believes that having the basic skill of representing an argument diagrammatically, even with paper and pencil, aids in the development of critical thinking skills. Yet her proposal as to the necessity of "research to determine whether the crucial factor is the mere ability to construct argument maps, or the aid of a computer platform and tutor, or possibly both" (Harrell 2008, p. 6) has not received sufficient attention.

Davies (2012, p. 24) also suggests that argument mapping is in its "early days in an experimental sense," and believes that "there is much work to do trialing this approach in different contexts." Furthermore, there appears to be some flaws in the methodologies applied in the past research which necessitates further research. For instance, to compare the critical thinking gains in argument mapping groups, some studies lacked control or comparison groups (Twardy 2004, van Gelder 2001) which affects the internal validity of the study (van den Braack et al. 2006, cited in Davies 2012). Moreover, as Dwyer et al. (2011) point out, the participants in some other studies (e.g., Butchart et al. 2009; van Gelder 2000) have not been randomly assigned to the experimental groups or matched in terms of critical thinking or cognitive ability or even thinking dispositions. Likewise, a study on the impact of CAAM on Iranian EFL majors' writing improvement failed to randomly assign EFL students to the experimental and control groups (i.e., Maftoon et al. 2014).

Despite the difficulties that students may face in learning language skills in Iran such as inability to express themselves in the foreign language setting as well as lack of receiving formal critical thinking education in their first language (Fahim and Saeepour 2011), critical thinking schooling and its effects on improving English language proficiency has recently captured the attention of Iranian EFL researchers (Barjesteh and Vaseghi 2012; Birjandi and Bagherkazemi 2010; Fahim and Ahmadian 2012). They have made efforts in recent years to both probe into the idea of critical thinking and its association with other constructs such as lexical inferencing (Mirzaie 2008) and autonomy (Sheikhy Behdani 2009), and to find out whether critical thinking skills instruction has a high degree of correlation with EFL learners' language proficiency (Fahim and Saeepour 2011; Barjesteh and Vaseghi 2012**).** Given the above arguments, the present study explored the effect of using technology (CAAM) on EFL learners' critical thinking skills development. Its design is in part in response to the criticisms of previous studies in the field of critical thinking mentioned above. In this study, the participants were randomly assigned into two experimental and one comparison groups. One experimental group received argument mapping instruction via Rational software and the other via paper and pencil; the comparison group only received traditional reading instruction. In addition, considering the conflicting research findings on the correlation between sex and performance on critical thinking tests (e.g., Barjesteh and Vaseghi 2012; Myers and Dyer 2006; Semeric 2010), the participants' level of reading proficiency as well as gender was taken into consideration. Hence the following research questions were posed:

(1) Is there any significant difference in Iranian EFL majors' overall critical thinking ability based on study format (*Rationale*, paper and pencil, comparison), sex (male, female), and reading proficiency levels (low, high)?
(2) Is there any significant difference in Iranian EFL majors' sub-skills ability of critical thinking (i.e., analysis, evaluation, inference, inductive and deductive reasoning) based on study format (*Rationale,* paper and pencil, comparison), sex (male, female), and reading proficiency levels (low, high)?

Methodology

This study intended to investigate whether practicing argument mapping as an approach to the promotion of critical thinking skills affect Iranian EFL students' reasoning and thinking skills. Therefore, a three-way ANOVA was used to assess the impact of teaching critical thinking through CAAM compared with both a conventional paper and pencil group and a no-treatment comparison group on overall critical thinking performance. To investigate participants' performance on critical thinking sub-skills (i.e., analysis, evaluation, inference, inductive, and deductive reasoning), MANOVA was used.

Context and participants

A sample of 207 EFL undergraduates who enrolled in two extra-curriculum reading courses infused with critical thinking plus a conventional reading class served as the participants of this study. However, during the course of the study, 27 participants were excluded due to missing either of the tests of FCE ($N = 2$) or post-test of CCTST ($N = 4$) or being in the intermediate proficiency group ($N = 21$) since the study intended to investigate low and high levels of reading proficiency. Thus the number of participants decreased to 180 who were randomly assigned to the three study groups. They were full-time undergraduate English Translation students with essentially identical study programs. They were recruited for the extra-curriculum courses via announcements and posters around the university, almost 1 month before the study was conducted. All participants were students of Aban University a city in the vicinity of Kashan, Isfahan and within the age range of 18–26. Participants were all informed about the nature and purpose of the study as well as their contribution to the advancement of the project. They were classified into high and low groups based on their scores on a sample First Certificate in English (FCE) reading test.

Instruments

A range of quantitative instruments was used in this study. The primary tool was a sample FCE reading test (2008) to assess the participants' reading proficiency level. Being among one of the four most popular ESOL (English for the speakers of other languages) exams in Iran, FCE includes three parts having 30 questions in total and it takes 60 min to be completed. Part one includes a text (i.e., a magazine article) followed by eight multiple choice questions. The second part also consists of a text (i.e., a newspaper article) from which seven sentences are removed and placed in a jumble order and part three includes several short descriptive texts preceded by 15 multiple-matching questions. Each correct answer in parts one and two receives two scores and in part three, one sore. The

reason why the reading section of FCE was administered was that all the participants were attending a reading course, whether infused with critical thinking or not (i.e., in the comparison group). As the FCE scores were normally distributed, grouping the participants into high and low levels of proficiency was done based on the mean and Standard Deviation (SD) of the participants' scores. In order to do so, those scoring within 1 SD below and above the mean were considered as having an intermediate proficiency level. Those falling above +1 SD were considered as the high proficiency group and those falling below -1 SD were included in the low proficiency group. The score difference between the high and low reading proficiency levels was 27 with the minimum score being 7 and the maximum score 34.

For various conceptualizations of critical thinking, there was a wide array of critical thinking measures available. Since in the present study, critical thinking was both theoretically and operationally based on skills identified by the Delphi report, CCTST was used for assessing the participants' critical thinking skills. CCTST includes 34 multiple questions measuring overall critical thinking skill as well as its major subscales of analysis (9 items), evaluation (14 items), inference (11 items), deductive reasoning (16 items) and inductive reasoning (14 items). According to the test manual, participants receive a total score, which indicates whether a respondent has the skills necessary to think critically, and subscale scores, that represent the number of correct answers within a given category (Laird 2005). Since each correct answer is given one score, the maximum total score is 34 which, in the range of 0–7, does not indicate evidence of critical thinking. In addition, scores in range 8–12 are considered *weak* and 13–18 are *moderate*, 19–24 are *strong,* and 25 or higher are *superior* (Catchings 2015). CCTST has three versions, including forms A, B, and 2000, each consists of 34 multiple-choice questions that are statistically equivalent and takes 45 min to be completed. The present study made use of form B, since its Persian version was available and its reliability and construct validity have already been measured by Khalili and Hossein Zadeh (2003). According to their study, form B has a reliability coefficient of .62 and high construct validity, which makes it suitable for distinguishing among different levels of critical thinking. In the current study, the reliability coefficient of CCTST were found to be .82, using Cronbach alpha.

The other instrument used was a software package called Rationale™ (van Gelder 2007), developed by Austhink Company and used for mapping arguments. The software helps users to process large integrated chunks of propositional information, using a visual-spatial form of representation. Rationale™ assists them in constructing box-and-arrow argument maps. It also provides an evaluation feature for judging and analyzing the strength of an argument. Furthermore, Rationale™ contains "basis boxes" which are used for presenting the information about the basis of a reason or objection (For example, a basis box may include a quote, personal experience, statistics, expert opinions, or a commonly held belief, etc.). In addition, propositions are color-coded so as to make a distinction between evidence *for* a claim from evidence *against* a claim. Green boxes show the reason or support for a claim while red and orange ones are the indicators of objection and rebuttals, respectively. To help learners identify the structure of reasoning, words or phrases called *indicators* are used. For instance, common reason indicators include *because, follows from, since*, or objection indicators are *although, however*, and *but*. (Fig. 1)

Data collection procedure

This study took place over a 12-week semester, during which the experimental groups attended a critical thinking-infused reading course. The reading course was selected for

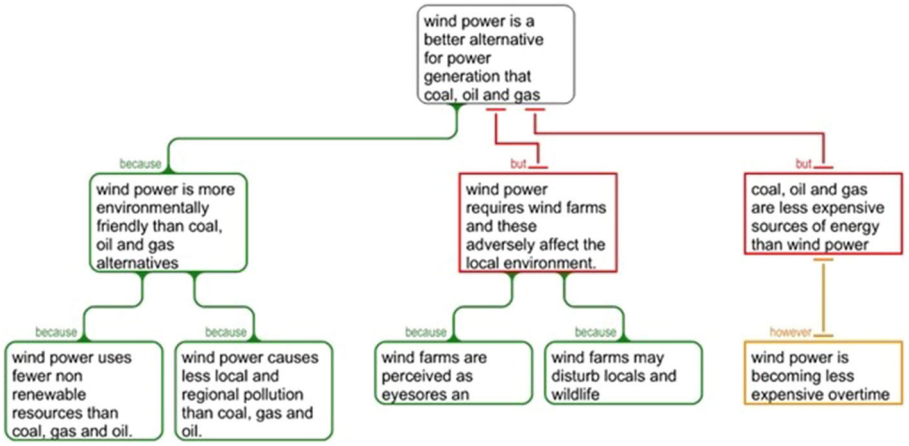

Fig. 1 Example of an argument map by Rationale^{TM} selected from the course materials

two reasons. First, since there is no critical thinking course in Iranian undergraduate curriculum as well as no specific textbook, the best possible course through which students could become familiar with arguments and have access to different argumentative and reasoning texts seemed to be a reading one infused with critical thinking. Second, the course content could explore often ethically or morally charged issues that are well suited for the methods used for analyzing arguments. Furthermore, critical thinking will be more relevant to the development of reading skills if, as Moon (2008) asserts, a sense of purpose directs the criticality.

Prior to the commencement of the instructional treatment, all the participants were divided into high and low reading proficiency levels based on their scores on a sample FCE test (2008). Then they were randomly assigned to three groups of 60 (i.e., two experimental and one comparison groups), each containing 30 students from high and 30 from low proficiency levels. The experimental groups were named *Rationale* and *Paper-and pencil* in accordance with the type of the treatment received. That is, the *Rationale* group attended a reading course infused with critical thinking where argument mapping was taught via Rationale^{TM} software and the Paper and pencil group received the same instruction via the traditional medium of paper and pencil. Since Rationale^{TM} software provides colorful maps, to homogenize the conditions, the paper and pencil group also practiced argument mapping via colored pencils.

In the opening session, both *Rationale* and paper and pencil groups were briefed about the nature of the study. They were also pretested with the Persian version of CCTST (form B) in the paper-based format. In sessions two, the course actually began and the training materials and exercises were delivered to the students. The substantive content of the materials including handouts, slides, and video clips were the same for both experimental groups despite the difference in terms of *Rationale* or paper and pencil presentation. Critical thinking skills and argument terminology (i.e., contention, reason, objection, rebuttal, etc.) were introduced in sessions two to six. During these sessions, students of both groups were also provided with argumentative texts of easy and small to more complex and large sizes and asked to read and interpret the prose. Then they were taught mapping skills and the way to apply such skills through presenting examples and exercises, each group based on the type of intervention received. Whereas the *Rationale* group was taught how to work with the software and construct argument maps in a computer

laboratory setting, the paper and pencil group practiced argument maps construction in a typical classroom equipped with the marker board and projectors. Instead of selecting a box, its location, and typing its relevant text as in the *Rationale* group, they drew out the boxes which were then filled by associated propositions and finally connected to arrows using only paper and pencil.

From weeks 7 to 11, the course focused on introducing critical thinking subscales (i.e., inference, evaluation, analysis, inductive and deductive reasoning). Students in both *Rationale* and paper and pencil groups were sequentially instructed how to extract the structure of the arguments (i.e., analysis sub-skill) by first reading the prose for an argument, locating logical indicators to set apart claims from extraneous verbiage, specifying the overall inferential structure of the prose, and finally visualizing them in the map. Then they were taught how to find the sources of arguments, judge their logical strength, relevance, and credibility (i.e., evaluation sub-skill), and draw reasonable conclusions (i.e., inference sub-skill). Eventually, they were taught inductive and deductive reasoning sub-skills through various examples and exercises so as to ensure that all critical thinking sub-skills measured by CCTST have been trained. They constructed and practiced argument maps of various sizes and difficulty levels. In fact, using Flesch-Kincaid readability formula the readability level of the course materials was calculated so as to select texts which are similar to that of the participants' textbooks. All unfamiliar words or grammatical structures were also clarified to let them better focus on the argument structure. Then the instructor assessed the maps provided by *Rationale* group using the *Evaluation* section in the toolbar of Rationale™ editor page. In the paper and pencil group, the participants received similar feedback in the form of oral or written comments by the instructor where required. They had to make necessary corrections and bring the revised maps back to the class in the following sessions or even they were sometimes asked by the instructor to proofread and give feedback on their peers' maps as a homework assignment. Finally the correct argument maps relevant to each prose were presented by the instructor as a basis for comparison. In the last session, the same form (B) of CCTST was administered to both groups as a post-test.

During the same interval (i.e., 12 sessions), the comparison group ($N = 60$) just received a conventional reading instruction which dealt with reading and discussing various text types including a random selection of texts from both their own reading textbooks as well as the argumentative texts that the experimental groups studied. No mention of critical thinking as well as argument mapping was made in the comparison class to avoid raising students' awareness of such skills. Instead of constructing argument maps, the comparison group were engaged in reading more text types and doing typical pre-reading and post-reading activities with a focus on a detailed understanding of the texts including the expression of main idea, detail, tone, as well as identifying text organizational features such as exemplification, comparison, etc. Similar to the experimental groups, the participants in the comparison group were pre-and post-tested with the Persian version of CCTST (form B). Each class of the three study groups met once a week for two-and-a-half hours and was taught by the first researcher.

Results

Using an alpha level of .05, the data (which enjoyed normality of distribution) was analyzed through a three-way ANOVA and a MANOVA. First, a three-way ANOVA was run to investigate the effect of study format (*Rationale*, paper and pencil, comparison), sex

(male, female), and reading proficiency levels (low, high) on Iranian EFL learners' overall critical thinking.

Table 1 displays the mean scores of the three study formats on the gain score of CCTST from pre-test to post-test. The software group showed the highest gain score on the CCTST. This was followed by paper and pencil and comparison groups.

As Table 2 indicates, there were significant differences between the three groups means on the gain score of CCTST (F (2, 168) = 9.60, $p < .05$, Partial $\eta^2 = .10$. Post-hoc Scheffé tests were conducted to compare the groups two by two. Based on these results (Tables 1 and 3) it can be claimed that:

- The software group ($M = 4.53$) significantly outperformed the paper and pencil ($M = 2.50$) group on the gain score of CCTST ($MD = 2.03$, $p = .04$).
- The software group ($M = 4.53$) significantly outperformed the comparison ($M = .96$) group on the gain score of CCTST ($MD = 3.58$, $p = .00$).
- There was not any significant difference between paper and pencil ($M = 2.50$) and comparison ($M = .96$) groups on the gain score of CCTST ($MD = 1.54$, $p = .17$).

As displayed in Table 4, the high proficiency group ($M = 2.81$, $SE = .47$) showed a higher mean on the total gain score of CCTST than the low proficiency group ($M = 2.51$, $SE = .47$), although the difference was not significant (F (1, 168) = .20, $p > .05$, Partial $\eta^2 = .001$).

Moreover, the female participants ($M = 2.77$, $SE = .47$) obtained a higher mean than the males ($M = 2.56$, $SE = .47$) on the total gain score of CCTST. However, the difference was not significant [F (1, 168) = .10, $p > .05$, Partial $\eta^2 = .001$]. Nor was a significant interaction effect found (Table 5).

A multivariate ANOVA (MANOVA) was conducted to investigate the effects of types of treatments, sex, proficiency levels and their interactions on the gain scores of the five components of critical thinking. Results revealed that there were significant differences between the three group means on the gain scores of all CCTST sub-skills with the greatest mean scores belonging to the inference and inductive reasoning followed by deductive reasoning, analysis and evaluation respectively (Table 6).

However, post hoc analyses (i.e., Scheffé tests) demonstrated that the software group significantly outperformed paper and pencil group just on the sub-skills of inference and inductive reasoning. Moreover, the software group gained significantly higher mean scores on all five CCTST sub-skills than the comparison group. However, the difference between the paper and pencil and comparison groups was not significant for any one of critical thinking sub-skills (See Table 7).

Considering the level of reading proficiency, results indicated that there was no significant difference between the high and low proficiency groups on the gain scores of overall CCTST and its sub-skills (see Tables 2 and 6). Nonetheless, while the high group

Table 1 Descriptive statistics; total gain CCTST by groups of learning

Group of learning	Mean	Std. error	95 % confidence interval	
			Lower bound	Upper bound
Software	4.537	.579	3.394	5.680
Paper and pencil	2.502	.579	1.359	3.645
Comparison	.960	.579	−.183	2.103

Table 2 Tests of between-subjects effects; total gain CCTST by groups

Source	Type III sum of squares	Df	Mean square	F	Sig.	Partial eta squared
Group	386.302	2	193.151	9.604	.000	.103
Level	4.140	1	4.140	.206	.651	.001
Sex	2.055	1	2.055	.102	.750	.001
Group × level	4.227	2	2.113	.105	.900	.001
Group × sex	49.969	2	24.985	1.242	.291	.015
Level × sex	8.899	1	8.899	.442	.507	.003
Group × level × sex	28.979	2	14.489	.720	.488	.009
Error	3378.886	168	20.112			
Total	5143.456	180				

Table 3 Multiple comparisons, total gain CCTST by groups

(I) Group of learning	(J) Group of learning	Mean difference (I − J)	Std. error	Sig.	95 % confidence interval	
					Lower bound	Upper bound
Software	Paper and pencil	2.03*	.819	.048	.01	4.06
	Comparison	3.58*	.819	.000	1.55	5.60
Paper and pencil	Comparison	1.54	.819	.173	-.48	3.56

* The mean difference is significant at the .05 level

Table 4 Descriptive statistics; total gain CCTST by proficiency levels

Level	Mean	Std. error	95 % confidence interval	
			Lower bound	Upper bound
High	2.818	.473	1.885	3.752
Low	2.515	.473	1.582	3.448

Table 5 Descriptive statistics; total gain CCTST by sex

Sex	Mean	Std. error	95 % confidence interval	
			Lower bound	Upper bound
Male	2.560	.473	1.627	3.493
Female	2.774	.473	1.840	3.707

gained higher mean scores on CCTST and analysis, evaluation, and inference, the low group gained slightly higher means on deductive and inductive reasoning. Similar to the level of reading proficiency, participants' sex had no significant difference on CCTST and its sub-skills performance (Tables 2 and 6). However, females gained higher mean scores on overall CCTST and evaluation, deductive and inductive reasoning, whereas males performed better on analysis and inference.

Table 6 Tests of between-subjects effects, gain analysis by group × proficiency × sex

Source	Dependent variable	Type III sum of squares	Df	Mean square	F	Sig.	Partial eta squared
Group	Analysis	369.100	2	184.550	7.951	.001	.086
	Evaluation	360.544	2	180.272	7.421	.001	.081
	Inference	424.078	2	212.039	9.432	.000	.101
	Deductive	369.678	2	184.839	8.360	.000	.091
	Inductive	399.633	2	199.817	9.156	.000	.098
Level	Analysis	21.356	1	21.356	.920	.339	.005
	Evaluation	15.022	1	15.022	.618	.433	.004
	Inference	.450	1	.450	.020	.888	.000
	Deductive	.050	1	.050	.002	.962	.000
	Inductive	.800	1	.800	.037	.848	.000
Sex	Analysis	.089	1	.089	.004	.951	.000
	Evaluation	8.022	1	8.022	.330	.566	.002
	Inference	.050	1	.050	.002	.962	.000
	Deductive	3.472	1	3.472	.157	.692	.001
	Inductive	3.756	1	3.756	.172	.679	.001

Table 7 Multiple comparisons, gain inference by groups for inference and inductive reasoning

(I) Group of learning	(J) Group of learning	Mean difference (I − J)	Std. error	Sig.	95 % confidence interval	
					Lower bound	Upper bound
Inference						
Software	Paper and pencil	2.35*	.866	.027	.21	4.49
	Comparison	3.72*	.866	.000	1.58	5.85
Paper and pencil	Comparison	1.37	.866	.290	−.77	3.50
Inductive reasoning						
Software	Paper and pencil	2.12*	.853	.049	.01	4.22
	Comparison	3.63*	.853	.000	1.53	5.74
Paper and pencil	Comparison	1.52	.853	.209	−.59	3.62

* The mean difference is significant at the .05 level

Discussion

The research questions compared the effect of critical thinking instruction via software and paper and pencil with a no training comparison group on overall critical thinking and its sub-skills performance of Iranian EFL students. Form B of CCTST was used both as the pre-test and post-test to check the participants' improvement before and after intervention. Results demonstrated the main effect of study format (or group) on CCTST and its sub-skills (see Table 1). That is, the software group significantly outperformed paper and pencil and comparison groups, gaining the highest CCTST and its sub-skills mean scores.

There are several justifications which explain this finding. One is the usefulness of CAAM via Rationale™, since as noted by van Gelder (2007), it helps improve reasoning skills by making students perform more deliberate practice than traditional approaches. In addition, map construction via software might enhance the brain's ability to comprehend reasoning by complementing what it could already do imperfectly. This is further confirmed by Davies (2009) who suggests that it links the brain's natural informality with the semi-formality of structured maps (Davies 2009).

Besides, as van Gelder (2003) puts it, the maps formerly constructed by the paper and pencil were static objects incapable of being modified by the user and required considerable time, as well as expertise. This method of argument mapping was criticized for being tedious and requiring specialist printing and careful design via pen and paper (van Gelder 2003). As such, constructing and modifying maps via paper and pencil might be time-consuming and tiresome, leading to lower mean scores which was also confirmed by the results of this study. In addition, the better performance of the software group might be due to the point that the software helps present information in an integrated, hierarchically organized method (van Gelder 2001) which, as Sweller (1999) asserts, leads to better and faster learning compared to map construction via paper and pencil.

Notably, results confirmed prior research findings (e.g., Butchart et al. 2009; Donohue, et al. 2002; Dwyer et al. 2010; Harrell 2011; van Gelder 2001; van Gelder, et al. 2004) which suggested a significant effect of CAAM instruction on critical thinking improvement. Moreover, results verified van Gelder et al.'s (2004) conclusion that to improve critical thinking, a semester-long course taught via argument mapping is required. Similarly, Donohue et al.'s (2002) series of eight studies in which students were asked to construct argument map via software (i.e., *Reason!able*) also showed significant changes in critical thinking ability of students during a single semester.

In her study, Harrell (2008) refers to the similar effect of argument mapping instruction via software on philosophy students' critical thinking skills development compared to other traditional tools. Focusing on the findings of two empirical studies and making use of relatively short and simple arguments, she concludes that what improves students' critical thinking skills is being able to construct an argument even with the use of rudimentary tools such as paper and pencil. However, findings from the present study demonstrate the positive effect that teaching argument mapping via the computer tutorial environment had on developing EFL learners' critical thinking skills compared to the traditional paper and pencil method, especially when constructing complex (i.e., large size) maps matters. Whereas, in Harrell's (2008) study, no matter which method of argument construction was used (i.e., chalk board, overhead slides, software, paper and pencil), participants in all groups who knew the argument mapping skill improved their critical thinking abilities. In this study, the software group outperformed those two groups displaying methods of map construction as well as the computer platform and technology. Moreover, the results of the current study are not totally consistent with the findings of Dwyer et al.'s (2011) study which only demonstrated a positive effect of argument mapping training via Rationale™ on the skills of evaluation and inductive reasoning.

The study results highlighted the importance of introducing higher-order thinking skills in foreign language classes as well (Chamot 1995; Chapple and Curtis 2000; Davidson 1994; 1995; Tarvin and Al-Arishi 1991). In line with Rezaei et al.'s (2011) suggestion, using critical thinking in language classes helps learners pose questions, search for reasons, and make good judgments. Besides, the findings support explicit approaches to teaching critical thinking that infuse it into course contents, thereby corroborating the findings of other studies (Abrami et al. 2008; Ramsay 2009; Solon 2007, van Erp 2008).

In addition to significant differences in the performance of the three study groups on overall CCTST and its sub-skills, the post hoc results demonstrated that the software group significantly outperformed the paper and pencil group on overall CCTST and the sub-skills of inference and inductive reasoning. One possible reason might be that these two sub-skills are closely related and are central in deriving conclusions (Dwyer et al. 2011; Godfrey-Smith 2008). Accordingly, learning one would positively facilitate the achievement of the other, leading to similar performance on the relevant sub-tests. Moreover, due to greater familiarity and engagement of students in the extra-curriculum course toward the end of the term, they have been highly motivated to actively attend the class and show a better performance on the subsequently taught skills including inference and inductive reasoning. The short space of time between practicing these skills and performance on CCTST post-test and thereby better memory recall can constitute another justification.

Regarding proficiency level, results revealed that those at high levels of reading proficiency did not significantly outperform students at low levels on CCTST and its sub-skills. Logically, students with high levels of reading proficiency should have comprehended and extracted the structure of the arguments, judged their logical strength, relevance, and credibility, and recognized the sources of arguments more successfully compared to low proficient ones. However, the study results propose that EFL majors' critical thinking skills do not vary across high and low levels of reading proficiency. Although students at higher levels of reading proficiency generally gained higher mean scores, the lack of significant differences between the two groups might indicate that critical thinking skills are more a matter of cognition rather than linguistic within an Iranian EFL context. Hence, it can be concluded that language skills such as second language reading proficiency and metacognitive processes such as critical thinking might not have much in common in an Iranian EFL setting.

Results therefore, are supported by the findings of several prior studies which demonstrated no significant correlation between students' level of English proficiency and their performance on CCTST (e.g., Barjesteh and Vaseghi 2012; Mulhall 2011; Tung and Chang 2009). However, they contradict some research findings which suggested a positive relation between reading proficiency and Iranian students' performance on CCTST (Aliakbari and Sadeghdaghighi 2011; Fahim et al. 2010; Hosseini et al. 2012).

Moreover, no main effect of sex on CCTST and its sub-skills performance was found, indicating that there was no significant difference in the performance of male and female students in an EFL context. Accordingly, both males and females were not advantaged in modern (i.e., software) or traditional (i.e., paper and pencil) instructional approaches used to teach critical thinking in the study. It is thus congruent with research findings (e.g., Barjesteh and Vaseghi 2012; Myers and Dyer 2006; Semeric 2010) including Terry and Ervin's (2012) study in which no statistically significant effect of factors such as sex and age on CCTST exam were found. This further confirms Facione's (1990b) conclusion that CCTST is not a gender-biased test. Nonetheless, a few studies (e.g., Aliakbari and Sadeghdaghighi 2011; King et al. 1990) pointed to the significant main effects of educational level and sex on tests of critical thinking with graduate students and males outperforming seniors and females.

Conclusion

The findings of this study confirmed the effectiveness of CAAM as a tool for enhancing critical thinking skills among Iranian EFL learners, and it has implications for EFL teachers and curriculum developers in contexts similar to that of EFL majors at Aban

University. Informed by the findings of present study, it is clear that CAAM can be applied as a teaching aid which lends support to text-based (prose) presentation of arguments. This can provide students with more opportunities to deeply understand the structure of the reasoning behind the arguments by grasping the associations among propositions and judging the credibility and logical strength of them. However, care must be taken when generalizing the results to other EFL contexts outside Iranian contexts.

Furthermore, based on Waters (2006) claim, providing EFL learners at various levels of proficiency with critical thinking activities will aid them in moving beyond the information within the text. Such cognitively challenging activities which facilitate better decision-making can encourage students to be fair-minded, as well. This can be feasible by first creating a classroom that supports collaboration, acceptance of opposite views and perspectives, and open expression of one's own beliefs without fear of being reproached.

Notably, technology enables the simulation of real-life situations by providing the chance to work on authentic tasks and a variety of ways to solve problems. It increases the learner's control of the learning process which in turn alters the roles of teachers and textbooks (Pusack and Otto 1997). In fact, it fosters their autonomy which is based on learners' ability to self-direct for practice, critical reflection, and independent action (Andrade 2012). Given the findings of the present study, it is crucial that EFL teachers in similar contexts enhance students' ability to comprehend and recall argumentative texts by presenting them hierarchically with the help of software since it assists students in gaining a deeper understanding of the materials. In addition, by reducing the cognitive load imposed on memory as well as constructing stronger memory links than the text alone, the software can motivate students to get engaged in deliberate practice (van Gelder 2005).

Within an Iranian EFL context, critical thinking has scarcely received due attention in order to be included in the curriculum of any discipline. There is also no specific formal course in relation to critical thinking. Hence, material developers and curriculum designers should be encouraged to pay considerable attention to methods of introducing and promoting critical thinking as well as devising formal and informal assessing tasks of this higher order thinking skill. One helpful approach, as proved effective by the findings of this study, is the infusion approach in which critical thinking skills are embedded into the course content and explicitly stated as an outcome (Abrami et al. 2008).

Future research is also required to explore critical thinking development in other EFL/ESL settings via manipulating the conditions of the experiment. For example, providing feedback for one experimental group and not the other, excluding color from the paper and pencil group, infusing critical thinking into a writing rather than a reading class, checking individual versus collaborative performance of students, and practice inside vs. outside the classroom can be among the objectives of future research.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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