Digital Authoring Support for Argumentative Writing: What does it change?

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Abstract: C-SAW (Computer-Supported Argumentative Writer) is an online authoring software embodying design principles derived from theories on written argumentation, self-regulation and conceptual change as well as feedback from practitioners and users, in line with a design-based research approach. Designed to scaffold writing processes, C-SAW is intended as additional support in instructional designs using argumentative writing for learning. This article presents the results of a mixed-method study comparing undergraduate students writing with C-SAW or a text editor. Outcome measures included the number of arguments and the degree of their completion, knowledge of argument components, topic knowledge and changes in epistemic beliefs. Participants writing with C-SAW elaborated arguments to a greater degree, but there were otherwise no significant differences between conditions for other measured outcomes. Furthermore, results were influenced by informal reasoning skills that outweighed the effects of condition. These results are discussed with respect to the difficulties of studying the effects of digital tools on writing and learning in controlled first-use contexts and the importance of developing instructional designs with explicit learning outcomes that are aligned to the instructional principles embedded in digital tools.

Keywords: argumentative writing, technology-enhanced learning, epistemic beliefs, digital writing support, writing-to-learn

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1. Introduction

Argumentative writing has been at the centre of pedagogical approaches using writing-to-learn and writing-across-the-curriculum to develop critical thinking, reasoning, and understanding (Bazerman et al., 2005; Klein, 1999). More recently, several publications have made a case for written argumentation across the curriculum for developing critical thinking and content knowledge, outlining differences and similarities in its uses for pedagogical purposes (Jonassen & Kim, 2010; Thompson, 2011, Wolfe, 2011). However, argumentative writing is a task that calls upon multiple and complex cognitive and metacognitive skills. In novice[1] writers of the genre, these skills must often be acquired along with the domain-specific learning outcomes that the argumentative writing process is expected to promote, with the quality of the argumentation within the text produced often serving as a measure of the attainment of the learning outcome.

Since the 1990s, there has been a proliferation of digital tools to support the development of writing skills, most of which aim at assessing the mechanics of writing (spelling, grammar, syntax, language use) (Strobl et al., 2018). In parallel, research in collaborative learning through dialogical argumentation has spurred the development of numerous computer-supported collaborative tools for representing and guiding debates and knowledge building (Scheuer, Loll, Pinkwart, & McLaren, 2010). However, few tools guide the development of strategies to help students transition from debate or other knowledge-building activities to written argumentative text.

This article is the part of an ongoing design-based research on digital support for scaffolding learning from, learning about, and learning to write argumentative texts. The design-based research approach was used with the aim to apply models, theories and research findings on writing processes, writing-to-learn, argumentation, self-regulation and conceptual change in the design of the Computer-Supported Argumentative Writer (C-SAW), an authoring tool for novices of argumentative writing. The aim of this study was to observe the effects of writing with C-SAW on generating arguments, learning about written argumentation and learning from the argumentative writing process.

2. Theoretical framework

Argumentative writing brings with it the benefits intrinsic to writing that have been at the core of *writing-to-learn* and writing across the curriculum movements since the 70s (Emig, 1977). Argumentation is proposed as a pedagogical approach because of the types of learning it promotes. Andriessen, Baker, & Suthers (2003) characterize three types of learning promoted through argumentation. Through the linguistic structures and conventions inherent in learning *to* debate, argumentation helps develop reasoning and critical thinking (Schneuwly & Dolz, 2010). Learning *about* debate requires that writers learn the structures used in argumentation so as to consider differing perspectives and understandings on a topic and confront and revise their views, thereby expanding the scope and depth of the knowledge to be integrated (Limón, 2001). Learning *from* debate occurs when learners engage in the analysis, evaluation, modification, and justification of their knowledge and beliefs, leading to changes in conceptual understanding and deeper learning (Kuhn, 2001). These are high demands that require the monitoring and self-regulation of one's activity (process and product) in the attainment of a set rhetorical goal (Bereiter & Scardamalia, 1987b). They are cited as the catalysts for the cognitive and metacognitive processing that allow for the elaboration and construction of knowledge (Bereiter & Scardamalia, 1987c). The resolution of cognitive conflict is central to engaging in the processes required for deeper learning and conceptual change, and argumentation provides the framework within which cognitive conflict can be invoked and resolved. By adhering to the *argument–counterargument–refutation* schema, learners are confronted with contradictory information. Differing views can be ignored or denied, admitted under certain conditions or integrated in a new proposition in an aim to resolve this cognitive conflict in a synthesis leading to the construction of new knowledge (Leitão, 2000).

Kuhn, Zillmer, Crowell, & Zavala (2013) present argumentation as a competence to develop epistemology. Personal epistemologies on the nature of knowledge and how we come to know are increasingly included as important factors to consider, not only in conceptual change models, but also in studies on argumentation (Cho & Jonassen, 2002). Personal epistemologies are tied to the ability to reason (Leitão, 2000; Limón, 2001; Mason, Ariasi, & Boldrin, 2011) and the willingness to reflect upon divergent views, and judge and evaluate conflicting information or evidence (Kuhn, 2001). Kuhn considered epistemologies as a progression from the belief in knowledge as directly knowable (*direct observation*), to knowledge as facts that are certain even if unknown (*absolutist*), to knowledge as opinions grounded in subjective perspectives (*multiplist*), to knowledge as uncertain and subject to evaluation and evolution (*evaluativist*). Mason & Scirica (2006) found that students with evaluativist epistemologies were best able to construct valid counterarguments and respond to them in ways that did not dismiss or ignore opposing views. Hofer (2000), identified two dimensions to personal epistemologies: beliefs in the nature of knowledge (*certainty* and *simplicity* of knowledge), and beliefs in the way we come to know (*justification*). She likens beliefs in knowledge as certain or simple to lower-level absolutist epistemologies.

2.1 Designing digital tools to support written argumentation

In the last two decades, numerous digital tools for supporting argumentation have been developed for use in research. Many have not outlasted their research funding and are no longer supported, while others have become pay-for-service or reserved for institutional use only (Strobl et al., 2018). Digital tools for argumentation are mainly of two non-exclusive types. The first supports idea generation and relationship building between concepts usually in the form of a diagram. These mostly help diagram arguments for and against through predefined argumentation models to guide reasoning in collaborative learning situations to draw attention to and promote the resolution of cognitive conflict. They aim to support valid argument construction for 'sense-making' or theory-building, to test concepts, theories and hypotheses through argumentation. The second supports the mechanical aspects of the quality of the *text product* (micro-level grammar, language use, sentence structure, macro-level organization).

A current review of digital tools for academic writing revealed several gaps in the support they offer (Strobl et al., 2018). There is a lack of tools to support *writing processes* at the macro-level (strategy development, self-monitoring, argumentative structure, rhetorical moves) and at the micro-level (reasoning, argument validity, and structure). Additionally, few tools found aimed to support the development of metacognitive skills and reflection. Reviews of computer-supported tools for collaborative argumentation and scientific inquiry (Clark, Stegmann, Weinberger, Menekse, & Erkens, 2007; Scheuer et al., 2010) also reveal a lack of support for writing processes (idea generation, text production, revising, organizing, connectors). These tools offer writers little instruction or guidance on how to organize and structure their arguments at the local level and integrate arguments into their writing at a global level to assure the development and cohesion of their texts in the attainment of a rhetorical goal. The transition from discourse, debate and argument construction to the written text product often used for evaluation of learning in educational contexts, is largely left to the novice writer.

In designing a digital authoring tool to support argumentative text writing two main areas of research were taken into consideration: (1) conditions for engaging in the resolution of cognitive conflict leading to deeper learning and conceptual change, and (2) the difficulties novices of the argumentative writing genre encounter when writing argumentative texts.

In the aim to better understand how to support the development of these skills and provide the conditions necessary, a design-based research (DBR) approach for designing instructional technologies was used in multiple cycles (Herrington, 2012; Reeves, 2000). This approach allowed us to define requirements based on literature and input from practitioners while taking context and users into consideration, so as to define design principles to guide the technological development and testing of C-SAW in a way that would not only help us refine the software, but also inform current research in the domain.

Novices of argumentative writing have difficulty generating ideas and developing arguments that are varied and valid (Kuhn, 1991), and constructing and organizing arguments and using connectives (e.g.: thus, but, therefore) (Dolz, 1996). Novices must also acquire sufficient task knowledge to apply the structure of discourse and its components (Bereiter & Scardamalia, 1987a; Flower, Hayes, Carey, Schriver, & Stratman, 1986) while recalling and reconstituting domain-specific topic knowledge (Leitão, 2000).

Scaffolding should support the self-regulation of procedural tasks aiming to reduce the cognitive load of the writing task by providing schemas and organizational devices that make the structural components of argumentative writing schemas explicit, especially where knowledge of the structure, conventions, and strategies of discursive writing may be minimal (Bereiter & Scardamalia, 1987b; Karoly, 1993; Nussbaum & Schraw, 2007). The consideration of multiple perspectives and the resolution of problems arising from contradictory information is often cited as the main mechanism leading to deeper learning through argumentative writing (Andriessen et al., 2003; Jonassen & Kim, 2010; Limón, 2001; Nussbaum & Schraw, 2007; Nussbaum & Sinatra, 2003; Wolfe, Britt, Petrovic, Albrecht, & Kopp, 2009). Activities or devices that can promote deeper reflection on one's own theories and how one has come to believe what they know should be integrated within the learning and writing task to evoke metacognitive thinking throughout the instructional sequence and writing task (Cotos, Huffman, & Link, 2020). This should be extended to reflection on counterarguments to support decentring—particularly during the construction of refutations to resolve cognitive conflict encountered—suggesting ways to evaluate one's thinking and reasoning, and the validity of proposed arguments (Felton & Herko, 2004).

The use of an authoring tool to support argumentative writing is based on digital tools' particular ability to serve as *mindtools* allowing learners to think differently about a task or topic (Jonassen & Carr, 2000). Digital tools can offer textual, graphic and visuo-spatial representations of concepts, their interconnections and an overall structural representation of one's knowledge (Janssen, Erkens, Kirschner, & Kanselaar, 2010). "*Embedding and fostering* argumentative *activities in learning environments promotes productive ways of thinking, conceptual change, and problem solving,*" (Jonassen & Kim, 2010, p. 439). Digital tools decompose tasks into subtasks or simplify tasks by helping learners focus their attention and guiding them to achieve a prescribed or desired state (Pea, 2004). By modeling routines and presenting schemas, digital tools guide learners in allocating cognitive resources, while helping them integrate schemas necessary for adopting effective strategies, thinking about their goals, and completing prescribed tasks. Digital writing tools offer the means use log file data to mirror writers activities and present past and possible courses of action (Vandermeulen, Leijten, & Waes, 2020). Digitally-supported argumentative writing software can buoy self-regulation and motivation during the task by offering dynamic progress indicators and mirroring writers' actions so they can monitor their progression with respect to the expected standard or schema, set goals and select strategies to achieve them (Soller, Martínez, Jermann, & Muehlenbrock, 2005).

2.2 C-SAW design

Two full DBR cycles were conducted to test the implementation in a digital writing tool of needs derived from the literature. The first sought to assure a coherence between research and user needs (practitioners and learners) in the development of the prototype. This first cycle resulted in a series of postulates giving way to four design principles. These principles propose a framework for instructional design and for designing tools to help learners engage in the cognitive and metacognitive processes that favour deeper learning and conceptual change in instructional settings using argumentative writing as a pedagogical approach. These principles were formalized in a markup language as an XML schema (ArgEssML) that also serves as a framework for the development of C-SAW. The second cycle tested C-SAW in a real classroom setting so as to refine the principles and the C-SAW interface. These principles are embodied in the interface and devices in C-SAW to scaffold the writing process, by guiding, supporting and reifying learners' actions.

C-SAW is a web-based authoring tool that provides a structural representation of an argumentative essay in three main text sections: an introduction, an arguments area, and a conclusion. Each text section is presented in sequence in one browser window and can be edited and saved separately by selecting its 'edit mode' which opens a view with all the editable text fields, menu options and prompts (Figure 1). Elements within section views contain labels and supplementary contextual aids for text fields to be completed. Writers can work through the sections in any order and view or print their text as a whole at any point. A graphic tree structure (Figure 2) shows which components have been filled and which are still empty (full or empty nodes) and gives a visual indication of writers' own rating of their product (increase or decrease in size). C-SAW only reflects writers' actions. It does not evaluate the quality of the text. Writers can freely add, delete or rearrange the order of arguments. All argument elements can also be saved in 'hidden' mode so as not to appear in final text output until desired.

2.3 Design principles embodied in devices

Based on research findings four design principles are embodied in the interface and its various devices. They are designed to represent and support argumentative writing processes.

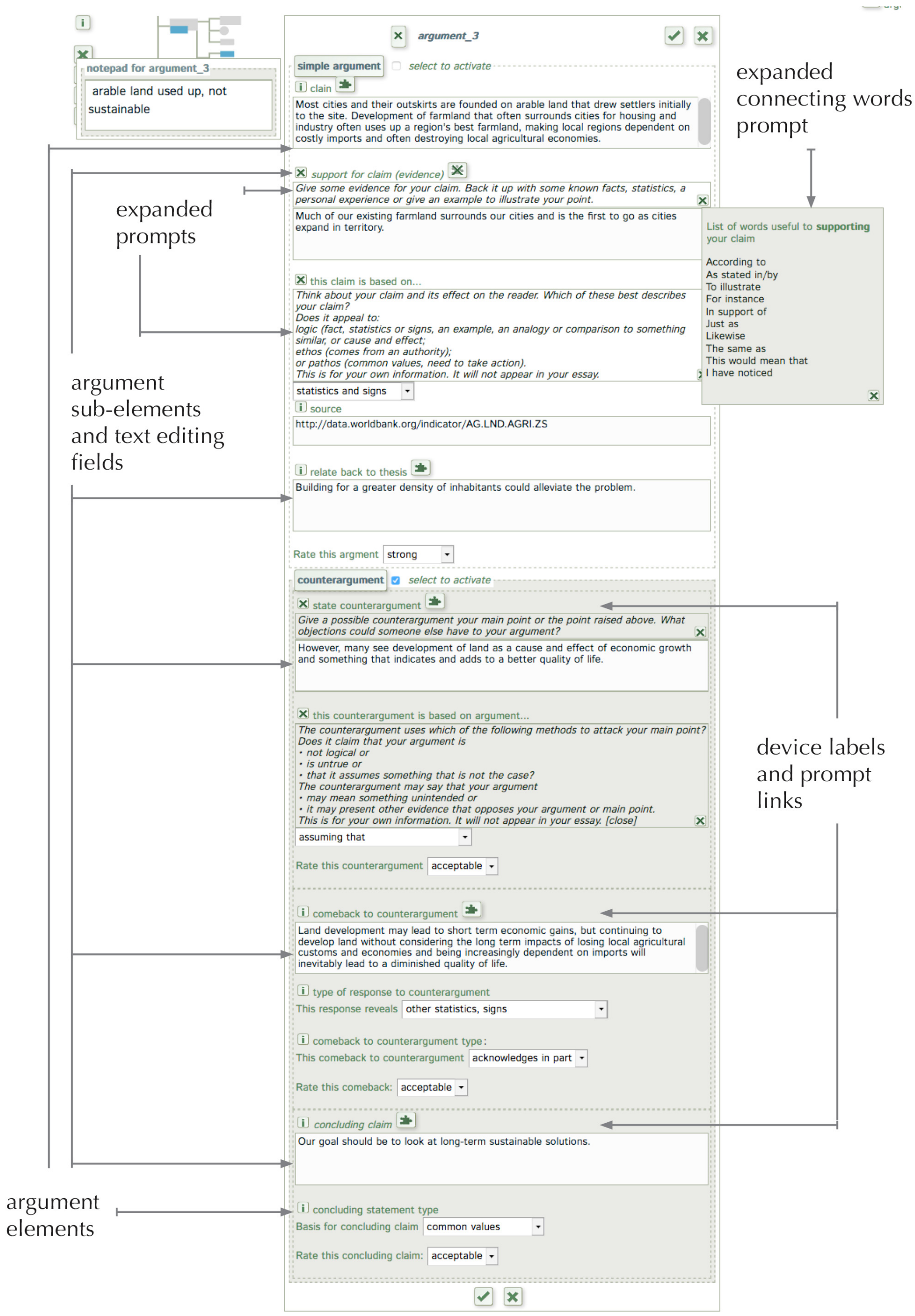

Figure 1: A view of an argument in edit mode. The simple argument content in hidden mode. A notepad, several contextual prompts, and a connectives list are visible.

Support knowledge of the structure of discourse in argumentative writing through global and local argument structural aid

Adhering to the structures and conventions particular to argumentative texts improves the quality of the argumentation, the text, and learning (Bereiter & Scardamalia, 1987b; Karoly, 1993). Offering explicit argumentation schemas and structural aids can free cognitive resources for the generation and elaboration of new ideas (Kanselaar, Erkens, Prangsma, & Jaspers, 2002). By offering structural aid learners can first follow, then adopt, and eventually internalize argumentation schemas (components and conventions), necessary to produce argumentative texts that adhere to the conventions of the genre.

C-SAW facilitates the adhesion to the structures and conventions of argumentative writing by offering a structure for global text organization: the introduction to define rhetorical goal; arguments to support rhetorical goal; the conclusion to assess goal progression and modify one's position accordingly. Local argument schemas help construct arguments: claim, counter-argument, rebuttal with an option to propose a new claim. Within each argument, a choice can be made whether to introduce a simple argument, a counterargument or a complex argument. The structured on-screen layout and editing options allow for recursive writing and editing while guiding the writer to adhere to the local and global structures of discourse and the proposed argumentative writing schema. Additional notepads are provided for each area to support free text generation, outlining ideas or note-taking at all stages and processes of writing.

Contextual cognitive aid through prompts

Cognitive aid, whether through prompts or graphical representations, should encourage idea generation, engagement in sound reasoning, information seeking, and perspective-taking (the generation and inclusion of counterarguments and refutations and the evaluation of their validity). In this way, it can promote the resolution of cognitive conflict in ways that expand and deepen knowledge and reflection, and are beneficial to learning (Andriessen, 2006; Erkens, Janssen, & Kirschner, 2010; Nussbaum & Schraw, 2007). Computer-supported argumentative writing software should scaffold the production of valid argumentation by supporting the development and linking of ideas to arguments and their components and their relation to the main rhetorical goal of the text. Context-specific linguistic aids can be provided to suggest terms to link ideas, promoting reasoning and elaboration in the construction of coherent arguments (Crewe, 1990; Means & Voss, 1996) so as to improve the quality of written arguments (Dolz, 1996).

C-SAW provides general unsolicited contextual prompts that equally serve as labels for each element and input. Additional contextual help can be solicited for each component and its elements and menu inputs by clicking labels and their icons (Figure 1). Prompts can refer to the function of a particular argumentation element or call upon writers to reflect on their reasoning and strategies. To scaffold informal reasoning, input menus are presented asking writers to attribute a basis for their propositions and to assess the validity of each argument element they present. These prompts provide information about argumentation but also serve to guide the writing process. Each text input element is accompanied by the option to solicit a list of context-specific connectives. These can help with formulating and linking ideas, but can also serve as 'prompts' as to what kind of information is expected within a particular element, guiding the search for appropriate ideas.

Mason (2002) presents a review of studies that show epistemic thinking can be developed through scaffolded activities that encourage meta-cognitive reflection. Pieschl et al. (2008) introduced epistemic sensitization to reading material and showed that it elicited more 'sophisticated' beliefs invoking more elaborate learning processes. Devices included in C-SAW are intended to scaffold the analysis and self-evaluation of the arguments writers present through self-identification of 'types' of arguments presented, fallacies detected and response strategies engaged so as to foster epistemic thinking.

Self-regulatory facilitators to aid self-monitoring, metacognitive reflection and task completion

The facilitation of self-regulatory mechanisms can lead to more elaborate argument development and a more cohesive overall structure by enabling writers to gain control over which writing process they should engage in and when (Breetvelt, Bergh, & Rijlaarsdam, 1994). Enhanced self-regulation and metacognitive reflection and awareness during the writing of argumentative texts can facilitate deeper reflection and understanding that can, over time, lead to conceptual change (Munneke, Andriessen, Kanselaar, & Kirschner, 2007).

Soller et al. (2005) suggest three types of self-regulatory tools that can be integrated with argumentation systems to facilitate self-regulation: *mirroring tools* to reflect available information on an interaction; *metacognitive tools* to propose possible courses of action according to the specified reference model; and *guiding systems* to compare the current to the desired state and offer appropriate guidance. Allowing writers to visualize and evaluate their progress can spur task completion and increase self-efficacy (Karoly, 1993; Schunk, 1996). C-SAW offers three devices that act as self-regulatory facilitators and may lead to an improvement of self-regulation:

Self-evaluation (*mirroring, metacognitive*) – Writers can evaluate each argument element (the ideas they produce) according to their own degree of satisfaction (weak, satisfactory, strong) with regards to the goals they have set. The rating strengths change the size of the nodes in the graphic tree map, mirroring their current evaluation (Figure 2). This trace of self-evaluation can serve as a metacognitive trigger to engage in further elaboration and revision of roughly sketched or unsatisfactory ideas.

Argument validation *(metacognitive, guidance*) – C-SAW also offers menus specific to the claim, the counterargument, the comeback, and the concluding claim elements. These menu options ask writers to indicate the basis and validity of their propositions. This is intended as a means to reflect upon their reasoning, and promote variation in types of propositions made (i.e.: not base all claims on personal experience). The options specific to each element are derived from Aristotelian informal reasoning (Aristotle, n.d.).

The graphic tree map represents the skeletal structure of the argumentative essay in the form of a hierarchical tree map generated from the XML data log file (Figure 2). It gives dynamic feedback, mirroring the current state of the essay. The graphic tree visually represents the introduction, each argument and the conclusion next to each editable area and remains visible during editing. Each text input element is represented as a node (rectangle for obligatory and circle for optional) and grouped according to its respective parent element. Hovering the cursor over a node gives the name of the element. Nodes are additionally colour-coded to show information on their state: full or empty to show where text has been introduced; blue to indicate a counterargument; and grey if disactivated to be excluded from the final text output. The graphic map is intended to work as a mirroring tool reflecting the current state, a metacognitive tool to guide further actions, and a guiding tool to aid task completion.

Multiple representations

Providing different visual and textual representations of argumentative writing schemas and task goals can act as meta-cognitive triggers to guide self-regulation and self-monitoring (Baker et al., 2003; Breetvelt et al., 1994; Erkens et al., 2002; Kanselaar et al., 2002; Nussbaum & Schraw, 2007). Structural tools, contextual aid and prompts, combined with mirroring tools and progress indicators can serve as metacognitive tools, to activate awareness of the cognitive and meta-cognitive processes and self-regulation necessary in the promotion of knowledge integration and conceptual change (Jonassen & Carr, 2000).

C-SAW offers multiple visual and textual representations reflecting writers' actions (current state, process, and progress) to help them recognize what they have achieved, what is lacking and direct their attention to appropriate tasks to achieve the desired outcome. Text produced in each section can be viewed alongside the editing view for comparison while editing. The entire text can be viewed in a separate window with contextual prompts inline or as plain text to be exported or printed.

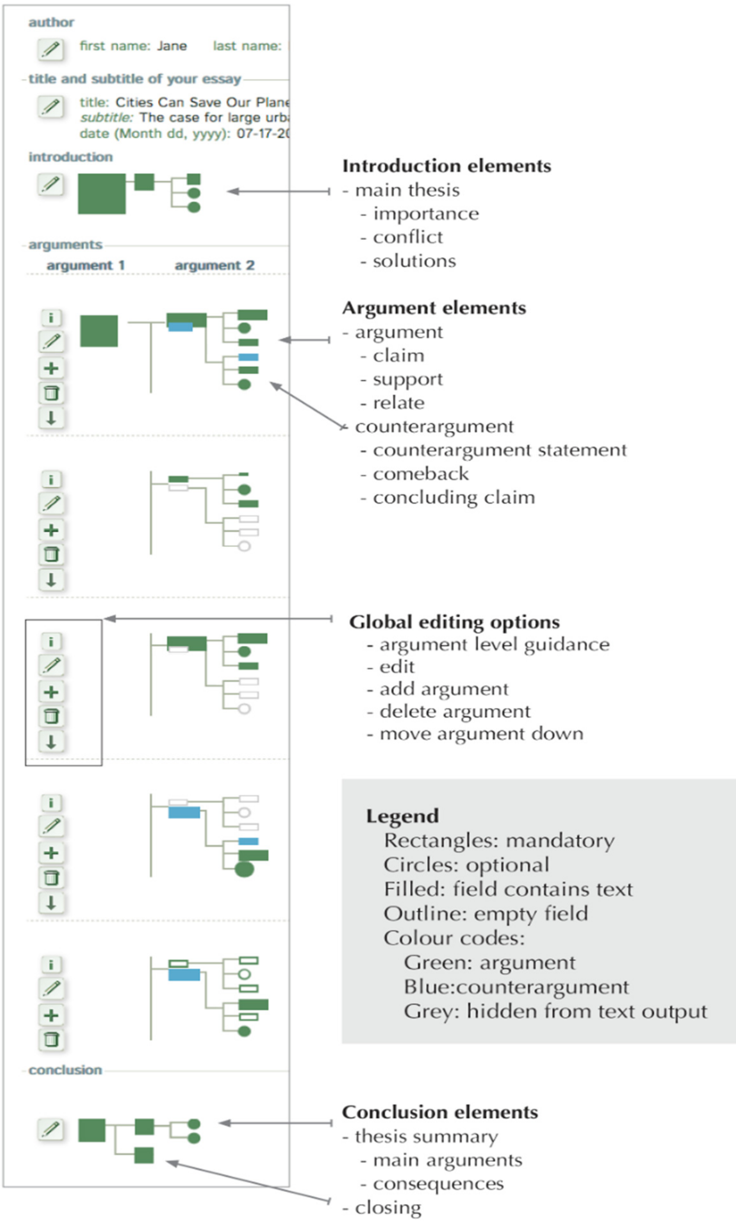

Figure 2: The graphic tree map with editing options for each area visually represents the schema of an argumentative essay. This tree shows the introduction and conclusion to be complete. There are 5 arguments. The first is a complete complex argument. The second and third are completed simple arguments. The fourth is a completed counterargument and the fifth an incomplete complex argument.

3. The Study

This study investigated whether the features embedded in C-SAW could support argumentative writing, learning about argumentation, and changes in declarative knowledge and epistemic beliefs about the certainty and simplicity of knowledge. The study also looked at informal reasoning as a possible covariate of these outcomes. A study using a quasi-experimental design was conducted comparing a group of undergraduate students using C-SAW with a control group using regular text processing software with external guidelines regarding argumentative writing.

In line with Kanselaar et al. (2002), C-SAW's built-in self-regulatory devices, and structural and organizational scaffolds during argumentative writing should support the generation and elaboration of arguments. Therefore, we expect that the number and completion of arguments (presenting claims, counter-arguments, and responses) will be higher in the CSAW group than in the control group (learning *to* argue).

The second hypothesis is that working with C-SAW's visual schema will help integrate knowledge about argumentative writing components (learning *about* argumentation). Therefore, the C-SAW group will show a greater increase in the number of components of argumentation they can list compared to the control group.

Finally, the scaffolding of reasoning and self-monitoring during the writing process would promote deeper learning through the modification of existing declarative knowledge and promote changes in epistemic beliefs about the *certainty/simplicity of knowledge* (learning *from* argumentation). Concretely, the changes in declarative knowledge on the topic and in epistemic beliefs should be greater in the CSAW group than in the control group.

4. Method

4.1 Participants

Participants were 23 undergraduate students (6 male, 17 female, age M=22 years, SD=4.5 years) from several disciplines: psychology and educational sciences (n=7), literary studies (n=3), pure and applied sciences (n=7), law (n=2), economy and social sciences (n=3), translation (n=1), who had sufficient knowledge of French to be studying at a Swiss French-language university. They were randomly assigned into two conditions: C-SAW (N= 12, 2 male, 10 female) vs. Text Editor (N= 11, 4 male, 7 female) as a control condition. Participants were recruited through postings on campus asking for participants who wished to learn to write argumentative texts. They participated on a voluntary basis and, as compensation for the length of the study, were remunerated 40.- CHF each upon completing all phases of the study. Considering the small compensation and the length and difficulty of the task, it seemed unlikely students with a good knowledge of argumentative writing would participate.

4.2 Experimental design

The experiment had a two-factor mixed design. The first factor, *writing tool*, was a between-groups measure with two levels: whether the participant wrote the argumentative text using C-SAW or used a standard text editor (MSWord) and external guiding support (see Learning task). The second factor, *time*, was a within-group measure with three levels: pre-test, immediate post-test, and delayed-test.

4.3 Material

Learning task

For the writing task participants were asked to express their views on genetically modified organisms (GMOs) in food production in an essay presenting three or more arguments opposing their views and to respond to them and include an introduction and conclusion. A simplified version of the C-SAW argumentation schema was used to present the suggested argument structure in both conditions (Figure 3). In C-SAW, the interface was modified to leave out the simple argument elements. In the control condition, the schema was presented in text format within a web page[2]. Instructions asked participants in both conditions to begin with counterarguments and then respond to them, with a requirement (rather than an option) to draw a conclusion from this 'debate', which then ends up serving as a claim. It was hoped that limiting participants to this argument model would reduce the first-use interface complexity, and force all participants to introduce counterarguments, to incite cognitive conflict and encourage them to resolve the conflict. This would make it more likely that participants would construct refutations that could then be analysed for their relationship to changes in declarative knowledge and epistemic beliefs.

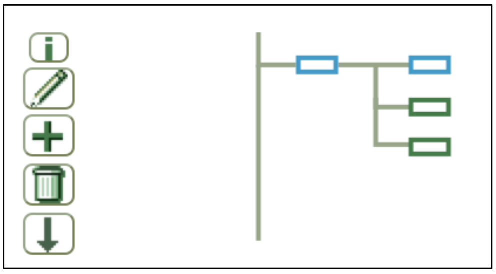

Figure 3: Argument model using only the counterargument–comeback–concluding-claim option.

During the writing task, participants were given supplementary material they could use to search for information. This material was provided in the form of 3 web pages that compiled information used in the SCALE Project (2002)[3]. This included facts and case-studies[4], scientific information[5] and various propositions presented as risks and opportunities[6].

Participants were supplied with the same computer workstation for all three sessions. The C-SAW group used a Firefox web-browser to access the C-SAW web-application and learning materials. The control group used a text editor (MSWord) to write their text and a Firefox web-browser to access learning materials. The C-SAW group was given a brief (about 5 minutes) introduction to the interface functionalities (meaning of icons and graphics, editing, saving, viewing) and had an online user-guide to which they could refer for manipulating the tool.

Instruments

Dispositions and knowledge that could moderate argumentative writing processes were measured before the writing activity and used as covariates if they differed significantly between groups.

Informal reasoning skills: A shortened version of Neuman's (2003) detecting fallacies informal reasoning task was used to measure informal reasoning skills (see Appendix 1). The test was shortened so as not to tire participants before the writing task, though this risked making it a less accurate measure. Only the first three questions of each problem, where the logical fallacy should be detected, described, and resolved were kept and only three tasks were presented per session, one from each type of reasoning fallacy. Each step in each question was given 1 point if it was correct for a score from 0 – 9 for each session.

Argumentation components: Knowledge about the components of argumentative texts were measured using an open question: *What parts or elements should an argumentative essay contain? List the components that make up the structure of an argumentative essay*. One point was given for each element listed, with a maximum score of 19 (one point for each item represented in the schema proposed to both conditions in the argumentative writing help).

Declarative knowledge about the topic: A 20-question multiple-choice quiz on declarative knowledge about of GMOs in food production was devised from 3 sources[7-8-9] to assess previous topic knowledge and any subsequent changes (see Appendix 1). Answers to all questions in the quiz were available in the resources given to participants.

Epistemic beliefs: Only the 20 items factoring into belief in the certainty and simplicity of knowledge from Hofer's Discipline-Focused Epistemological Beliefs Questionnaire (Hofer, 2000) were used for the questionnaire on epistemic beliefs (EB score): 11 items questioned about knowledge in general (GE score) and 9 items were phrased to question beliefs about knowledge specific to the domain of biotechnologies (DSE score).

4.4 Procedure

The study ran for three sessions over a 4-week period totaling 4.5 hours. The first session (pre-test) lasted 2 hours. All participants completed the declarative knowledge quiz, the argument components list, the epistemic beliefs questionnaire, and the informal reasoning task prior to beginning the writing activity. They wrote for the remainder of the two hours. The second session (post-test) one week later, also ran for 2 hours. All participants began by completing the writing task, then completed the declarative knowledge quiz, the epistemic beliefs questionnaire, the argument components list, and the informal reasoning task. Though the overall time spent writing over the two sessions varied between one to two hours, all participants completed their texts in the time allotted. Participants returned 10 -14 days later (delayed-test) for a half-hour session to again complete the epistemic beliefs questionnaire, the argument components list, the informal reasoning task, and the declarative knowledge quiz. All questions within the quiz, questionnaire, and task were randomized for each participant during each session to avoid any ordering effects and all participants completed all tasks well within the time limits of each session.

4.5 Data analysis

Informal reasoning: The task was given during each session. A repeated-measures ANOVA was performed to measure possible effects of time or condition or if informal reasoning could be treated as a covariate. Each step in each question was given 1 point if it was correct for a score from 0 – 9 for each session.

Idea generation (number of arguments): For the number of arguments, we counted how many initial counterarguments each participant presented within their text.

Argument completion: For argument completion, we counted the number of argument sub-elements. One point was given for each sub-element (counterargument, comeback, concluding claim) included in an argument and divided by the number of counterarguments presented by each participant.

Argumentation components: One point was given for each component listed that was represented in the schema proposed to both conditions in the argumentative writing help. The maximum score possible was 19 points.

Declarative topic knowledge: One point was awarded for each correct answer of the 20-item quiz. Declarative knowledge was measured through the quiz scores in the pre-test, post-test, and delayed-test scores. The same quiz was given each session.

Epistemic beliefs: The adapted questionnaire had an acceptable internal consistency of $\alpha = .629$ on pre-test measures. Questions were scored on a 5-point Likert scale with 1 point for strong disagreement to 5 points for strong agreement with each statement presented. Higher scores indicated a stronger belief in the certainty and simplicity of knowledge associated with dispositions less conducive to conceptual change (Mason, 2003). Epistemic belief scores were measured in the pre-test, post-test, and delayed-test. The minimum score possible was 20 points and the maximum was 100.

5. Results

It was hypothesized that using C-SAW would favourably impact learning to argue (number and completion of arguments), learning about written argumentation (listing argument components) and learning from written argumentation (increase in declarative knowledge and a change in beliefs in the certainty and simplicity of knowledge).

Table 1 displays the scores for the informal reasoning task in the pre-test, post-test, and delayed tests for the two conditions and the scores averaged over the three sessions.

Table 1: Means for pre-test, post-test and delayed-test measures for informal reasoning skills

Time	Pre-test		Post-test		Delayed-test		Average over 3 sessions	
Condition	Text n = 11	C-SAW n = 12	Text Editor n = 11	C-SAW n = 12	Text Editor n = 11	C-SAW n = 12	Text Editor n = 11	C-SAW n = 12
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Informal reasoning	4.82 (1.47)	3.75 (1.87)	4.73 (2.10)	3.33 (1.92)	5.09 (1.58)	3.92 (2.11)	4.88 (1.37)	3.67 (0.96)

A repeated-measures ANOVA showed a significant difference between conditions (F(1, 21) = 6.16, p = .02, partial η2 = .23). However, there was no interaction or effects between time and condition (F=.05, p = .95). As such, the scores from the three sessions were averaged to give the informal reasoning score for each participant.

Additionally, an independent samples t-test showed that the difference in informal reasoning scores between the Text Editor condition and the C-SAW condition averaged over the three sessions was statistically significant, t(21) = 2.48, p = .02, d = 1.03. As a result, informal reasoning skills were considered as a covariate in all analyses. Data were analysed with 2 (condition: CSAW vs. text editor group) × 3 (time: pre-test, post-test and delayed test) mixed-design analyses of variance with informal reasoning as covariate (ANCOVA). Partial eta-squared was used to determine the effect size with values of .01, .06 and .14, corresponding to small, medium and large effects respectively (Cohen, 1988).

5.1 Learning *to* argue

It was hypothesized that those writing with C-SAW would generate more arguments and complete arguments to a greater degree than those writing with the text editor. Table 2 and Table 3 present the descriptive statistics for the number of arguments and level of argument completion respectively. Independent samples t-test were conducted on both measures.

Table 2: Number of arguments presented

Condition	M	SD	N
Text Editor	2.91	0.944	11
C-SAW	3.42	1.084	12
Total	3.17	1.029	23

Table 3: Level of argument completion

Condition	M	SD	N
Text Editor	2.48	0.807	11
C-SAW	3.28	1.082	12
Total	2.90	1.023	23

An ANCOVA with informal reasoning as a covariate showed there were no significant differences in the *number of arguments* presented between conditions, F(1, 20) = 2.05, p = .17, partial η2 = .09.

The difference between the two groups regarding *argument completion* was significant, with the C-SAW condition completing argument elements to a greater level. An ANCOVA with informal reasoning as covariate yielded a significant main effect of condition in argument completion, $F(1, 20) = 6.153$, $p = .02$, partial $\eta 2 = .24$ (large effect).

5.2 Learning *about* written argumentation

Table 4 displays the scores on the knowledge of *argument components* in the pre-test, post-test, and delayed test for the two conditions. With the pre-test mean scores of both conditions being between 5 and 6 points out of 19, they were considered novices with respect to the knowledge of argumentative text components expected. Descriptively, the scores for both groups remained low in both conditions.

A mixed measures ANCOVA with time and condition as independent variables showed no significant differences between or within conditions and no interaction (all Fs < 1). A significant main effect of the covariate variable informal reasoning was shown, $F(1,20) = 5.19$, p - .03, $\eta 2 = .21$.

5.3 Learning *from* written argumentation

Table 4 displays the scores for declarative knowledge in the pre-test, post-test, and delayed test for the two conditions. A repeated-measures ANOVA with informal reasoning as a covariate showed no significant difference in declarative knowledge quiz scores between or within conditions and no interaction (all Fs < 1). Descriptively, the scores remained low in both conditions.

Table 4: Means for pre-test, post-test and delayed-test measures

Time	Pre-test		Post-test		Delayed-test	
Condition	Text Editor (n = 11)	C-SAW (n = 12)	Text Editor (n = 11)	C-SAW (n = 12)	Text Editor (n = 11)	C-SAW (n = 12)
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Argument components	5.91 (1.76)	5.08 (2.58)	7.09 (3.11)	6.08 (2.35)	6.91 (2.63)	6.83 (2.48)
Declarative knowledge	5.82 (2.32)	4.75 (1.60)	6.64 (2.42)	5.25 (1.42)	6.55 (1.97)	5.08 (2.07)
Epistemic beliefs	51 (5.50)	51.67 (7.83)	51.36 (5.12)	48.67 (6.72)	51.64 (6.49)	47.92 (7.49)

Table 4 displays the scores for epistemic beliefs in the pre-test, post-test, and delayed tests for the two conditions. A repeated measures ANCOVA conducted with time (pre-test, post-test, and delayed test) and condition (Text Editor vs CSAW) and informal reasoning as a covariate showed no significant differences in pre-test, post-test, and delayed-test measures between conditions, $F(1, 20) = 2.72$, $p = .12$, partial $\eta 2 = .12$.

6. Discussion

In this experimental study, we looked at the effects of using C-SAW, an online authoring tool designed specifically to scaffold processes involved in learning *to* argue, learning *about* argumentation and learning *from* argumentative writing. C-SAW uses the argumentative writing schema to support the integration of new knowledge through the resolution of cognitive conflict using refutation-based argumentation. Studies on the effects of cognitive conflict in learning measure the effects on concepts and beliefs following a learning activity where new and possibly conflicting concepts are introduced. In argumentation, it is measured through the number of counterarguments presented or refutations, or changes in position as evidenced in the written production or other measures of knowledge acquisition (Nussbaum & Schraw, 2007; Luna, Villalón, Mateos, & Martín, 2020). We looked at each of these through the number of arguments presented, their level of completion and changes in topic knowledge and epistemic beliefs. We additionally looked at changes in knowledge about argumentative writing components and declarative knowledge to measure learning on task and topic respectively.

6.1 Learning to argue

Munneke et al. (2007) found reasoning could be promoted through explicit representations and embodied guidance and feedback outlining the schema to help "broaden and deepen the space of debate" using diagramming. We hypothesized that C-SAW's explicit schema and guidance would incite participants in this condition to introduce more arguments and complete them to a greater degree than participants in the control condition writing with a text-editor. Using C-SAW did not lead to introducing significantly more arguments but it did lead to a greater level of completion of arguments—presenting a counterargument, comeback and a concluding claim—compared to the control condition. In this study, we saw that providing an explicit schema to be completed helped argument completion, which is a first step in this direction.

Bell (2000) found that generic prompts spurred more reflection than directed, specific prompts. The explicit schema graphic representation may have guided writers to see gaps in their texts, encouraging argument completion. Participants using the text editor had to access static help on a separate web page. They then had to extrapolate pertinent information and apply it to the writing or reflection process in which they were engaged. This required more cognitive resources, particularly working memory, that were then not available for reflection on the topic and conceptual level. As a result, the Text Editor condition participants completed their arguments to a lesser degree. In this case, C-SAW seems to have been supporting meta-cognitive processes aimed at self-regulation and meta-cognitive strategy selection through the guidance embedded in the interface, inciting them to complete their arguments to a greater degree. However, participants in CSAW did not generate more arguments than the Text Editor group, which may be related to the fact that no guidance or incentive was provided to prompt for the generation of more arguments.

6.2 Learning about written argumentation

This study also aimed to explore the effects of writing argumentative texts with C-SAW on learning about written argumentation, postulating that by following the schema and using the embedded help, participants would learn about the structures and conventions of argumentation and integrate these into their writing. Since C-SAW's interface explicitly embodies these and makes them directly available, participants in this condition would learn more about the components of argumentative writing than participants in the control condition that had to refer to external information outside of their writing environment. The information provided on argumentative writing components (within prompts or externally) did not result in significant increases in knowledge about argumentative writing components for either condition. As suggested in Nussbaum and Schraw (2007) participants may have possibly been following the model available that they were instructed to follow, but without integrating its details into their representations of written argumentation. This type of knowledge acquisition may need more explicit instruction and time.

6.3 Learning from written argumentation

One of the design goals of the development of C-SAW is to support learning from written argumentation. Schwonke et al. (2012) found that offering prompts with meta-cognitive support mediated the use of help in intelligent tutoring systems, thereby improving learning outcomes. The schema and contextual help in C-SAW were designed to support the resolution of cognitive conflict by scaffolding the generation of counterarguments and responses to counterarguments. Thus, it was hypothesized that writing with C-SAW would lead to greater declarative topic knowledge and a move to more sophisticated epistemic beliefs shown through decreases in the belief in the certainty and simplicity of knowledge. This scaffolding of the writing of more complete arguments appears to have had little effect on either topic knowledge or epistemic beliefs for either condition. As with learning about written argumentations, participants may have been only superficially following instructions inferred from the interface without further reflection and integration.

Studies on the effects of instructions have shown that learners interpret learning goals and use them to either include or exclude ideas in their written product (Leitão, 2003; Nussbaum & Kardash, 2005). In this study, participants had no explicit instruction on the topic and no other explicit learning goals. They could only infer learning goals from the task, and given the experimental setting, it is possible that learning was not seen as the primary goal, and even if it were, participants could have chosen to focus more on either the task or the topic. Following the 3rd session, one participant of the treatment condition offered opinions on the usability of C-SAW, having interpreted the writing task as an excuse to test the usability of the software.

6.4 Limits and perspectives

One of the main limitations of this study was the small sample size[10]. Informal reasoning has been shown to be a factor in the understanding of resources presented and argumentation quality (Means & Voss, 1996; M. Weinstock, Neuman, & Tabak, 2004). Better informal reasoning has also been associated with more sophisticated epistemic beliefs (Weinstock, Neuman, & Glassner, 2006). This was particularly problematic because informal reasoning skills differed significantly between conditions. It was also was a main effect in argument components measures. Furthermore, Klein and Kirkpatrick (2010) propose that instruction on topic and genre knowledge affect learning from the writing activity. The small sample size limited the types of analyses that could be conducted to study these factors more closely, for example binning participants into high and low informal reasoning skills, previous topic or task knowledge within conditions, which could have given more insight into how C-SAW effects low or high achieving individuals in these areas.

This study reveals the difficulty in seeking to isolate and study the effects of devices and their uses without a purposeful instructional design targeting specific learning outcomes. C-SAW was not designed as an autodidactic system, but as a support to instruction on argumentative writing or to support instructional designs where argumentation is being used to explore various points of view and resolve cognitive conflict using the structures and conventions of argumentation, with the expectation that this process will favour learning. C-SAW is a *support* that can lend itself to many types of argumentative writing instruction, for example, strategy instruction, process writing, peer revision, or collaborative writing. It can be used for pre-writing activities: idea generation, drafting and planning, organizing and developing texts, revising texts, and even deconstructing existing texts. By providing text fields and prompts as to the type of information that should be introduced, C-SAW could conceivably be used to analyze existing argumentative texts. For example, learners could extract from an original text, all claims for or against a particular thesis statement and insert them into appropriate fields. This could serve to help learners identify and understand arguments presented within a text and the purpose they serve, as well as offer insight into how learners interpret the argumentative function of text components, while being introduced to C-SAW's interface. C-SAW's components and devices aim, to varying extents, to support a variety of activities, but the pedagogical scenarios and approaches, prior instruction, learning outcomes, and instruction methods are expected of the instructor.

Instructional technologies can only be effective when goals are specified and the approach is well-aligned to the particular mediation the tool is designed to offer (Depover, 2014). Writing instruction can also be more effective when designed to heed discipline-based terms and conventions (Klein & Boscolo, 2015). The design of C-SAW assumes writers, though they may be novices, have received some instruction on argumentation and argumentative writing and any discipline-specific guidance to reasoning required. Learners should not be encountering terms, structures or concepts for the first time through the interface, but should be using C-SAW to scaffold the writing and thinking process as they learn to work within the structures and conventions of argumentation. With no explicit instructional design or goals, the pedagogical approach implied through the tasks proposed was autonomous auto-didactic learning through individual exploration alone. This was not aligned with C-SAW's intended use as a support to pedagogical scenarios with defined goals. To facilitate integration within disciplines and contexts, the current version of C-SAW under development, allows instructors to modify the terminology used and adapt the help to offer templates customized to their pedagogical discipline related needs.

As the goals were not specified, the help was not particularly adapted to the discipline and the approach not well-aligned to the mediation that C-SAW was designed to offer, it made it difficult to measure C-SAW's effectiveness with respect to the learning outcomes we defined as our dependent variables. To more accurately assess C-SAW's effectiveness as a support to argumentative writing, the design principles embedded in C-SAW should also be reflected in the lesson plan and instruction on argumentation for those that lack this knowledge. The principles should extend to the scenario as a whole and not be relegated to technological support only.

Studying the effectiveness of educational technologies involves not only observing outcomes, but also the way participants use technologies to achieve their tasks, particularly emerging patterns of use and their effects and how these evolve over time. This study observed only initial use patterns. Observing emerging utilization schemes and their effects was limited as these take time to emerge (Beguin & Rabardel, 2000). Participants using C-SAW were still in the initial stages of instrumentation. Research on effects of computer-supported interventions surveyed by van den Braak et al. (2006) shows the limits of studies on the effects of educational technologies due to not giving participants time for instrumental genesis. The instrumentation process limits the initial effectiveness and the study of the effects of the tool, which may in part explain why only argument completion emerged as a significant difference between conditions. The real problem lies in that until users have completed the process of instrumentation, for example, they can manipulate C-SAW as well as the control group can manipulate their text editor, there is no valid way to compare two groups, as instrumentation may be using up cognitive resources that cannot be effectively allocated to the writing task. This alone can severely influence outcomes. But providing enough time for instrumental genesis would bias any test group which would have more 'practice', thus threatening the validity of findings.

To counter these issues future experimental designs could present instruction on argumentative writing and argumentation models followed by an argument analysis activity where one condition would highlight text components and the other would copy and paste them into the appropriate editing field. But to fully understand how C-SAW can support argumentative writing based instructional designs, C-SAW needs to be used with instruction and pedagogical approaches aligned with its embodied principles.

Notes

1. Novice refers to writers that are learning to write argumentative texts and are not yet at ease writing in this textual genre regardless of age or schooling.
2. https://tecfa.unige.ch/perso/benetos/argumenter/argumentationInfos.html (Date accessed: 2019-10-23)
3. http://scale.emse.fr/scale_tools/tutorial+examples/Training_Expe/pws/experiment/lyon/expe/dossier/dossier.html 12 March 2014
4. https://tecfa.unige.ch/perso/benetos/argumenter/faits.html (Date accessed: 2019-10-23)
5. https://tecfa.unige.ch/perso/benetos/argumenter/ogm.html (Date accessed: 2019-10-23)
6. https://tecfa.unige.ch/perso/benetos/argumenter/arguments.html (Date accessed: 2019-10-23)
7. Quiz yourself about foods made from genetically modified crops: http://www.purdue.edu/uns/html4ever/0007.Goldsbrough.foodquiz.html (Date accessed: 2019-10-23)

8. Understand GMO crops? Test yourself with this quiz: https://news.uns.purdue.edu/html4ever/0007.Goldsbrough.cropquiz.html (Date accessed: 2019-10-23)
9. Genetically modified food products quiz: http://www.discovery.com/tv-shows/curiosity/topics/genetically-modified-food-products-quiz.html (Date accessed: 2014-03-03) - access to this web domain is restricted to certain geographical regions and could no longer be accessed from the authors' geographical location.
10. As the study occurred just prior to exam sessions, recruiting participants for 4.5 hours for 3 sessions over 4 weeks proved difficult.

References

Andriessen, Jerry. (2006). Arguing to learn. In R. K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences* (pp. 443–459). New York, USA: Cambridge University Press. https://doi.org/10.1017/CBO9780511816833.027

Andriessen, Jerry, Baker, M., & Suthers, D. D. (2003). Argumentation, computer support, and the educational context of confronting cognitions. In J. Andriessen, M. Baker, & D. Suthers (Eds.), *Arguing to learn: Confronting cognitions in computer-supported collaborative learning environments* (Vol. 1, pp. 1–25). Dordrecht, The Netherlands: Kluwer Academic Publishers. https://doi.org/10.1007/978-94-017-0781-7_1

Aristotle. (n.d.). On Sophistical Refutations. Retrieved from http://classics.mit.edu/Aristotle/sophist_refut.1.1.html

Baker, M., Quignard, M., Lund, K., & Séjourné, A. (2003). Computer-supported collaborative learning in the space of debate. In B. Wasson, S. Ludvigsen, & U. Hoppe (Eds.), *Designing for Change in Networked Learning Environments : Proceedings of the International Conference on Computer Support for Collaborative Learning 2003,* (pp. 11–20). Dordrecht, The Netherlands: Kluwer Academic Publishers. https://doi.org/10.1007/978-94-017-0195-2_4

Bazerman, C., Little, J., Bethel, L., Chavkin, T., Fouquette, D., & Garufis, J. (2005). Writing to Learn. In C. Bazerman (Ed.), *Reference Guide to Writing Across the Curriculum* (pp. 57–65). West Lafayette, Indiana, USA: Parlor Press and The WAC Clearinghouse.

Beguin, P., & Rabardel, P. (2000). Designing for instrument-mediated activity. *Scandinavian Journal of Information Systems*, *12*(1), 173–190.

Bell, P. (2000). Scientific arguments as learning artifacts: designing for learning from the web with KIE. *International Journal of Science Education*, *22*(8), 797–817. https://doi.org/10.1080/095006900412284

Bereiter, C., & Scardamalia, M. (1987a). An attainable version of high literacy: Approaches to teaching higher-order skills in reading and writing. *Curriculum Inquiry*, *17*(1), 9–30. https://doi.org/10.1080/03626784.1987.11075275

Bereiter, C., & Scardamalia, M. (1987b). Knowledge telling and knowledge transforming in written composition. In S. Rosenberg (Ed.), *Advances in applied psycholinguistics* (Vol. 1–2, pp. 142–175). CUP Archive.

Bereiter, C., & Scardamalia, M. (1987c). *The psychology of written composition*. (C. Bereiter & M. Scardamalia, Eds.), *The Modern Language Journal* (Vol. 73). Hillsdale, NJ: Lawrence Erlbaum Associates. https://doi.org/10.4324/9780203812310

Breetvelt, I., Bergh, H. Van Den, & Rijlaarsdam, G. (1994). Relations between writing processes and text quality: When and how? *Cognition and Instruction*, *12*(2), 103–123. https://doi.org/10.1207/s1532690xci1202_2

Cho, K., & Jonassen, D. H. (2002). The effects of argumentation scaffolds on argumentation and problem solving. *Educational Technology Research & Development*, *50*(3), 5–23. https://doi.org/10.1007/BF02505022

Clark, D. B., Stegmann, K., Weinberger, A., Menekse, M., & Erkens, G. (2007). Technology-Enhanced Learning Environments to Support Students' Argumentation. In S. Erduran & M. P. Jiménez-Aleixandre (Eds.), *Argumentation in Science Education. Science & Technology Education Library, vol. 35* (pp. 217–243). Dordrecht, The Netherlands: Springer. https://doi.org/10.1007/978-1-4020-6670-2_11

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum Associates.Crewe, W. J. (1990). The illogic of logical connectives. *ELT Journal*, *44*(4), 316–325. https://doi.org/10.1093/elt/44.4.316

Cotos, E., Huffman, S., & Link, S. (2020). Understanding graduate writers' interaction with and impact of the Research Writing Tutor during revision. *Journal of Writing Research 12*(1), 187-232. https://doi.org/10.17239/jowr-2020.12.01.07

Depover, C. (2014). Les dispositifs de formation médiatisés et leurs effets. In C. Peltier (Ed.), *La médiatisation de la formation de de l'apprentissage* (pp. 121–133). Louvain-la-Neuve, Belgium: de Boeck. https://doi.org/10.3917/dbu.peter.2014.01

Dolz, J. (1996). Learning argumentative capacities: A study of the effects of a systematic and intensive teaching of argumentative discourse in 11-12 year old children. *Argumentation*, *10*(2), 227–251. https://doi.org/10.1007/BF00180727

Erkens, G., Janssen, J., & Kirschner, P. A. (2010). Visualization of argumentation as shared activity. In J. E. Lieven Verschaffel, Erik de Corte, Ton de Jong (Ed.), *Use of Representations in Reasoning and Problem Solving: Analysis and Improvement* (p. 242). Taylor & Francis. https://doi.org/10.4324/9780203847824

Erkens, G., Prangsma, M. E., Jaspers, J., & Kanselaar, G. (2002). *Computer support for collaborative and argumentative writing*. *Onderwijskunde*. Utrecht, The Netherlands: ICO-ISOR Onderwijsresearch Universiteit.

Felton, M. K., & Herko, S. (2004). From dialogue to two-sided argument; Scaffolding adolescents' persuasive writing. *Journal of Adolescent & Adult Literacy*, *47*(8), 672–683.

Flower, L., Hayes, J., Carey, L., Schriver, K., & Stratman, J. (1986). Detection, diagnosis, and the strategies of revision. *College Composition and Communication*, *37*(1), 16–55. https://doi.org/10.2307/357381

Herrington, J. (2012). Design-based research: Implementation issues in emerging scholar research. In *EdMedia: World Conference on Educational Media and Technology* (Vol. 1, pp. 1–6). Chesapeake, VA: Association for the Advancement of Computing in Education (AACE).

Hofer, B. K. (2000). Dimensionality and disciplinary differences in personal epistemology. *Contemporary Educational Psychology*, *25*(4), 378–405. https://doi.org/10.1006/ceps.1999.1026

Janssen, J., Erkens, G., Kirschner, P. A., & Kanselaar, G. (2010). Effects of representational guidance during computer-supported collaborative learning. *Instructional Science*, *38*(1), 59–88. https://doi.org/10.1007/s11251-008-9078-1

Jonassen, D. H., & Carr, C. S. (2000). Mindtools: Affording multiple knowledge representations for learning. In S. P. Lajoie (Ed.), *Computers as cognitive tools, Volume 2: No more walls* (pp. 165–196). Mahwah, NJ, US: Erlbaum. https://doi.org/10.1201/ 9781315045337

Jonassen, D. H., & Kim, B. (2010). Arguing to learn and learning to argue: Design justifications and guidelines. *Educational Technology Research and Development*, *58*(4), 439–457. https://doi.org/10.1007/s11423-009-9143-8

Kanselaar, G., Erkens, G., Prangsma, M., & Jaspers, J. (2002). Using Tools in Computer Supported Collaborative Argumentation. *Utrecht University*, *20*.

Karoly, P. (1993). Mechanisms of self-regulation: a systems view. *Annual Review Psychology*, *44*, 23–52. https://doi.org/10.1146/annurev.ps.44.020193.000323

Klein, P. D. (1999). Reopening inquiry into cognitive processes. *Educational Psychology*, *11*(3), 203–270. https://doi.org/10.1023/A:1021913217147

Klein, P. D., & Kirkpatrick, L. C. (2010). A Framework for Content Area Writing: Mediators and Moderators. *Journal of Writing Research*, *2*(1), 1–46. https://doi.org/10.17239/jowr-2010.02.01.1

Klein, P. D., & Boscolo, P. (2015). Trends in research on writing as a learning activity. *Journal of Writing Research*, *7*(3), 311–351. https://doi.org/10.17239/jowr-2016.07.03.01

Kuhn, D. (2001). How do people know? *Psychological Science*, *12*(1), 1–8. https://doi.org/10.1111/1467-9280.00302

Kuhn, D., Zillmer, N., Crowell, A., & Zavala, J. (2013). Developing norms of argumentation: Metacognitive, epistemological, and social dimensions of developing argumentative competence. *Cognition and Instruction*, *31*(4), 456–496. https://doi.org/10.1080/07370008.2013.830618

Leitão, S. (2003). Evaluating and selecting counterarguments: Studies of children's rhetorical awareness. *Written Communication*, *20*(3), 269–306. https://doi.org/10.1177/0741088303257507

Leitão, S., Leita, S., & Leitão, S. (2000). The potential of argument in knowledge building. *Human Development*, *43*(6), 332–360. https://doi.org/10.1159/000022695

Limón, M. (2001). On the cognitive conflict as an instructional strategy for conceptual change: a critical appraisal. *Learning and Instruction*, *11*(4–5), 357–380. https://doi.org/10.1016/S0959-4752(00)00037-2

Luna, M., Villalón, R., Mateos, M., & Martìn, E. (2020). Improving university argumentative writing through online training. *Journal of Writing Research 12*(1), 233-262. https://doi.org/10.17239/jowr-2020.12.01.08

Mason, L. (2002). Developing epistemological thinking to foster conceptual change in different domains. In M. Limón & L. Mason (Eds.), *Reconsidering Conceptual Change: Issues in Theory and Practice* (pp. 301–335). Kluwer Academic Publishers. https://doi.org/ 10.1007/0-306-47637-1_16

Mason, L., Ariasi, N., & Boldrin, A. (2011). Epistemic beliefs in action: Spontaneous reflections about knowledge and knowing during online information searching and their influence on learning. *Learning and Instruction*, *21*(1), 137–151. https://doi.org/10.1016/j.learninstruc.2010.01.001

Mason, L., & Scirica, F. (2006). Prediction of students' argumentation skills about controversial topics by epistemological understanding. *Learning and Instruction*, *16*(5), 492–509. https://doi.org/10.1016/j.learninstruc.2006.09.007

Means, M., & Voss, J. (1996). Who reasons well? Two studies of informal reasoning among children of different grade, ability, and knowledge levels. *Cognition and Instruction*, *14*(2), 139–178. https://doi.org/10.1207/s1532690xci1402_1

Munneke, L., Andriessen, J., Kanselaar, G., & Kirschner, P. (2007). Supporting interactive argumentation: Influence of representational tools on discussing a wicked problem. *Computers in Human Behavior*, *23*(3), 1072–1088. https://doi.org/10.1016j.chb.2006.10.003

Neuman, Y. (2003). Go ahead, prove that God does not exist! On high school students' ability to deal with fallacious arguments. *Learning and Instruction*, *13*(4), 367–380. https://doi.org/10.1016/S0959-4752(02)00011-7

Nussbaum, E. M., & Kardash, C. M. (2005). The effects of goal instructions and text on the generation of counterarguments during writing. *Journal of Educational Psychology*, *97*(2), 157–169. https://doi.org/10.1037/0022-0663.97.2.157

Nussbaum, E. M., & Schraw, G. (2007). Promoting argument-counterargument integration in students' writing. *The Journal of Experimental Education*, *76*(1), 59–92. https://doi.org/10.3200/JEXE.76.1.59-92

Nussbaum, E. M., & Sinatra, G. M. (2003). Argument and conceptual engagement. *Contemporary Educational Psychology*, *28*(3), 384–395. https://doi.org/10.1016/S0361-476X(02)00038-3

Pea, R. D. (2004). The social and technological dimensions of scaffolding and related theoretical concepts for learning, education, and human activity. *The Journal of the Learning Sciences*, *13*(3), 423–451. https://doi.org/10.1207/s15327809jls1303_6

Pieschl, S., Bromme, R., Porsch, T., & Stahl, E. (2008). Epistemological sensitisation causes deeper elaboration during self-regulated learning. In *Proceedings of the 8th International Conference on International Conference for the Learning Sciences - Volume 2* (pp. 213–220). Utrecht, The Netherlands: International Society of the Learning Sciences.

Reeves, T. C. (2000). Enhancing the worth of instructional technology research through "design experiments" and other development research strategies. In *International perspectives on instructional technology research for the 21st century, New Orleans, LA, USA*. New Orleans, LA, USA.

SCALE Project. (2002). *Internet-based intelligent tool to Support Collaborative Argumentation-based LEarning in secondary schools*. Scale3 (University of Utrecht) and Scale4 (University of Jyväskylä). Project funded by the European Community under the Information Societies Technology (IST) Programme (1998-2002). Lead partner: University of Jyväskylä, Finland.

Scheuer, O., Loll, F., Pinkwart, N., & McLaren, B. M. (2010). Computer-supported argumentation: A review of the state of the art. *International Journal of Computer-Supported Collaborative Learning*, *5*(1), 43–102. https://doi.org/10.1007/s11412-009-9080-x

Schneuwly, B., & Dolz, J. (2010). Apprendre à rédiger un texte argumentatif sur la question de la violence: quel(s) objet(s) d'enseignement-apprentissage en classe de français ? *Canadian Education Association (CEA)*, *50*(3).

Schunk, D. H. (1996). Goal and self-evaluative influences during children's cognitive skill learning. *American Educational Research Journal*, *33*(2), 359–382. https://doi.org/10.3102/00028312033002359

Schwonke, R., Ertelt, A., Otieno, C., Renkl, A., Aleven, V., & Salden, R. J. C. M. (2012). Metacognitive support promotes an effective use of instructional resources in intelligent tutoring. *Learning and Instruction*, *23*, 136–150. https://doi.org/10.1016/j.learninstruc.2012.08.003

Soller, A., Martínez, A., Jermann, P., & Muehlenbrock, M. (2005). From mirroring to guiding: A review of state of the art technology for supporting collaborative learning. *International Journal of Artificial Intelligence in Education*, *15*(4), 261–290.

Strobl, C., Ailhaud, E., Benetos, K., Devitt, A., Kruse, O., Proske, A., & Rapp, C. (2018). Digital support for academic writing: A review of technologies and pedagogies. *Computers & Education*, *131*(September 2018), 33–48. https://doi.org/10.1016/j.compedu.2018.12.005

Weinstock, M., Neuman, Y., & Tabak, I. (2004). Missing the point or missing the norms? Epistemological norms as predictors of students' ability to identify fallacious arguments. *Contemporary Educational Psychology*, *29*(1), 77–94. https://doi.org/10.1016/S0361-476X(03)00024-9

Weinstock, M. P., Neuman, Y., & Glassner, A. (2006). Identification of informal reasoning fallacies as a function of epistemological level, grade level, and cognitive ability. *Journal of Educational Psychology*, *98*(2), 327–341. https://doi.org/10.1037/0022-0663.89.2.327

Wolfe, C. R. (2011). Argumentation across the curriculum. *Written Communication*, *28*(2), 193–219. https://doi.org/10.1177/0741088311399236

Wolfe, C. R., Britt, M. A., Petrovic, M., Albrecht, M., & Kopp, K. (2009). The efficacy of a web-based counterargument tutor. *Behavior Research Methods*, *41*(3), 691–698. https://doi.org/10.3758/brm.41.3.691

Vandermeulen, N., Leijten, M., & Van Waes, L. (2020). Reporting writing process feedback in the classroom: Using keystroke logging data to reflect on writing processes. *Journal of Writing Research 12*(1), 109-140. https://doi.org/10.17239/jowr-2020.12.01.05

Appendix A: Sample questions from instruments

Examples of questions of declarative knowledge

What are the current benefits of having foods made from genetically modified crops?
As a result of genetically modified crops, chemical use on farms has: …
Can genes escape from genetically modified crops and jump to other plants?

Examples of epistemic beliefs questionnaire

If teachers would stick more to the facts and talk less about ideas, one could get more out of college.
O strongly disagree O disagree O neutral or maybe O agree O strongly agree

All experts in this field would probably come up with the same answers to questions in this field.
O strongly disagree O disagree O neutral or maybe O agree O strongly agree

Example of a detecting fallacies informal reasoning task (Neuman, 2003).

The full task is shown.
Do UFOs exist?

1. Don and Henry are high school students.
2. During a lesson they debate the question: "Do UFOs exist?"
3. Don argues that UFOs exist.
4. Henry argues that UFOs do not exist.
5. During the debate Don argues: "No one has proven that UFOs do not exist, therefore we can conclude that UFOs exist."

The following questions were presented one at a time
Do you think that there is a problem in the argument Don presented in line 5?" (yes or no)
If you think that there is a problem in the argument presented by Don, what is the problem?
What is the best answer Henry can use in response to Don's argument?