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Argument Visualization with DMaps: Cases from Postsecondary Learning

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The Dialectical Map (DMap) is an open-source, web-based argument visualization tool developed and used at a Canadian University to scaffold argument construction. To illustrate the ways that argument mapping can be used in undergraduate courses, this article presents five cases selected from courses in biology, psychology, computing science, and English as a foreign language offered at three post-secondary institutions. Each case explains how argument mapping with DMaps (DMapping) was implemented and assessed in a course. Students responded to a questionnaire that gathered their attitudes toward DMapping as a learning activity. In each course, students were also interviewed about their DMapping experiences. The interview and questionnaire data indicated that students believed DMapping was an effective way to meet the knowledge objectives of their course and to learn about argumentation. The authors explain how DMap assignments added value to their courses by helping students think critically about course topics while developing their argumentation ability and information literacy. Finally, we summarize the lessons learned across the cases and discuss ways of maximizing the benefits of argument mapping activities for post-secondary learning.

Keywords: Argument Mapping, Visualization, Argumentation, Scaffold, Tertiary, Postsecondary, Writing, Tool

Argument Visualization in the Undergraduate Curriculum

Argument visualization, also known as argument mapping, has two fundamental applications in the undergraduate university curricula. One application is in philosophy courses which teach the analysis of others' arguments by having students translate provided argumentative texts into graphic representations that explicitly label the argumentative functions of text components (Davies, 2011; Harrell, 2011). A different application of argument visualization, the one featured in this article, is in supporting students'

construction of arguments. In this application, a student is asked to justify their position on a controversial topic by constructing an argument map. Argument mapping may be designed as a standalone assignment, a prewriting activity for an argument essay assignment, or some other learning activities.

The ability to compose and present arguments founded on evidence and reasoned criticism is often understood as a fundamental goal of university education (Wolfe, 2011). Accordingly, courses across a wide range of disciplines assign students to write argument essays, prepare for debates, and explain their reasoning in online discussions. Argumentation can also be engaged less explicitly in specialized genres such as science lab reports and business case studies.

For a variety of reasons, undergraduate students often struggle to form well-structured arguments. They may have never received training in argumentation, or they may have studied the principles of argumentation only to abandon them when faced with other challenging requirements of an assignment, such as library research and formal academic writing. To address these challenges, argument mapping software can be used as a cognitive tool to support students in learning to construct good arguments. The theoretical advantage of such tools is that through repeated interaction with an interface representing the structure of complete arguments, students internalize that structure as a cognitive schema and learn to proficiently compose arguments without reliance on the tool (Pakdaman-Savoji et al., 2019).

Computer-assisted argument visualization tools developed to support reasoning outside educational contexts have been repurposed to support student learning. Repeated argument mapping assignments using *ARTOO*, which was developed to assist scientists who create biological simulations to justify their design decisions (Alden et al., 2015), was found to enhance the higher-order thinking skills of pre-service teachers (Yilmaz-Na & Sönmez, 2023). A series of eight writing sessions using *Rationale*, which was developed to assist lawyers who develop legal cases (van Gelder, 2007), significantly improved undergraduate students' essay writing (Robillos, 2021). Student use of argumentation visualization platforms developed specifically to support learners, several of which accommodate collaborative argumentation, have been found to benefit scientific understanding (Bell, 2001), essay writing (Fan & Chen, 2021), and critical thinking (Butchart et al., 2009). A full review of research on the effects of argumentation visualization is beyond the scope of this article.

Using Visualization Tools to Construct Arguments

Standalone Assignment. Perhaps the simplest way to use argument maps in undergraduate teaching is to have students construct them for a standalone assignment. In this usage, the argument map assignment is structured like an argument essay assignment. As with an essay assignment, all students in a class might be required to address the same thesis (main claim), or they might be expected to choose separate theses. Typically, students would be previously trained in how to find research in bibliographic databases and how to follow conventional formats (e.g., APA) for citing references. Instructors should develop and disseminate to students a grading rubric that specifies how points will be assigned for various argument components. The rubric would typically indicate the expected scope and depth of the work by describing an approximate number for each type of argument component, and it would indicate the expected quality of the work by describing the expected qualities of each type of argument component. For example, the rubric might require a single thesis statement (i.e., main claim) that is clear, concise, and contestable. The standalone argument mapping assignment serves as a building block for constructing more complex and extended argument projects. If the goal is to focus on developing skill in argumentation per se, instructors might assign a series of standalone argument maps. But if the goal is to develop transferability of argument-related knowledge across different expressive media or communication contexts, an instructor can develop multi-part activities in which argument mapping is combined with separately assessed activities such as bibliographic search, essay writing, oral presentation, class debate, online discussion, etc.

Prewriting Assignment. The most common usage of argument mapping in a multi-part learning activity is likely as a prewriting (i.e., preparatory) assignment to be followed by an argument essay assignment addressing the same thesis. This type of learning activity allows students to receive feedback on an argument before it is deployed as the foundation of an essay assignment. They can export content from the argument map into a text document where they shape and elaborate the argument to create the essay. The strength of the essay format relative to the map format is that the essay allows more fulsome expression of contextual and rhetorical content that enhances the relevance and persuasive power of the argument. The rubric for the essay part of the assignment should emphasize argument features that are usually ignored or downplayed in argument maps, such as an introduction that serves to activate readers' prior knowledge and attitudes toward the topic of the essay. This type of multi-part assignment ensures students give attention to both the logical and rhetorical aspects of effective argumentation.

Other Learning Activities. There are many other uses of argument mapping in the undergraduate classroom. Instructors can form students into small groups whose members collaborate to construct argument maps. Students can individually construct argument maps that are assessed by their peers. They can construct argument maps to prepare for classroom presentations or debates. Instructors should, of course, choose and shape argument map learning activities to fit instructional goals, and each feature of the activities should be justified by reference to those goals.

The purpose of this article is to show how one argument visualization tool, the Dialectical Map (DMap), has been used in undergraduate courses to support several of the instructional activities mentioned above at Simon Fraser University (SFU), the British Columbia Institute of Technology (BCIT), and South China Agricultural University (SCAU)[1]. For each of the five cases, we describe how and why DMapping was incorporated into an assessed learning activity and how the activity was experienced by students. The article also presents results from a survey of students' attitudes toward their DMapping experience.

The Dialectical Map

Based on the Argument Vee Diagram designed by Nussbaum and Schraw (2007), the Dialectical Map is a web-based argument mapping application developed at Simon Fraser University (Nesbit et al., 2019). Students access a DMap created by their instructor from a link provided on an assignment page in a Learning Management System (LMS). Clicking the link creates the student's own copy of the DMap which they can edit and eventually submit as a completed assignment to the LMS.

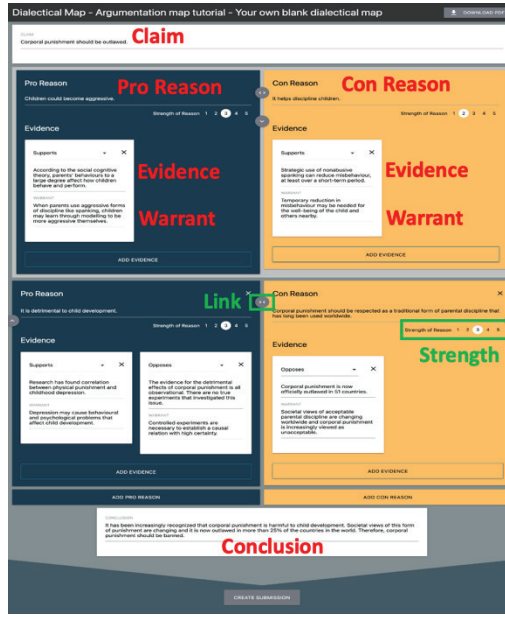
As shown in Figure 1, a text box for a concise statement of the thesis or main claim is featured at the top of every DMap. Instructors can assign the same thesis to a whole class by prefilling the thesis box or they can leave it blank so students can construct their own theses. Unlike node-link argument mapping applications, the DMap has a bilateral structure, with the reasons supporting the thesis presented on the left side and the reasons opposing the thesis on the right. Students enter a synthesis of the argument in a conclusion box at the bottom of their DMap. They are expected to develop a conclusion that considers the strength of reasons from both sides of the argument. Students can move reasons up or down on the page. When a pro and con reason are recognized as directly contradicting each other (i.e., one

[1] Ethical approval for the research was obtained from each of the institutions.

is a counterargument to the other) they can be 'locked' so that they travel together when one is moved. Students can self-evaluate the strength of their reasons on a scale from 1 to 5.

Figure 1

DMap Interface Overview



Students enter a pro or con reason in a text box that is visually connected to evidence panels. Each evidence panel has one text box for entering supporting or opposing evidence and one text box for entering a warrant. The warrant is a statement that explains or justifies why the evidence supports or opposes the reason (Toulmin, 1958).

Since 2016, the DMap application has gone through several revision cycles in which feedback from instructors and students was used to improve the interface. The cases, summarized in Table 1, feature courses taught in 2021 and 2022, all of which used the same version of the DMap application. In all cases except case 5, the DMaps constructed by students were assessed as part of the course grade, and in all cases except case 1, there was assessment of an additional product associated with the DMap.

In each case, semi-structured interviews were conducted to further explore students' experiences and attitudes toward the DMap assignments. This paper presents student responses to questions about the perceived benefits and challenges of studying with the DMap, selected by a team of at least two researchers to ensure that they represented ideas frequently expressed by students.

Table 1

Summary of Cases

Case	Discipline	Instructional Function of DMapping	No. Students	Assessments
1	Evolutionary Biology	Focusing on construction and assessment of arguments	68	DMap only
2	Computing Science	Collaborative argumentation for information literacy instruction	103	DMap + Bibliography
3	Educational Psychology	Managing the cognitive load of argumentative writing	320	DMap + Argument Essay
4	Psychology	Promoting construction of balanced arguments	81	DMap + Argument Essay
5	English as a Foreign Language	Developing argumentative writing in English	91	DMap + Argument Essay

Case 1. Evolutionary Biology – Focusing on Construction and Assessment of Arguments

A key learning outcome adopted by SFU's Department of Biological Sciences states that students earning a BSc should be able to develop coherent arguments supported by relevant, credible evidence. DMap assignments have been used in several courses in the department including *Introduction to Biology*, *General Biology*, *Vertebrate Biology*, and *Evolution*. In lower division courses, DMap assignments require students to engage with controversial public policy issues (e.g., "Wolves should be killed to protect endangered caribou in British Columbia"), or competing academic hypotheses (e.g., "Dogs and wolves are the same species"). In more advanced courses, DMap assignments address competing academic hypotheses (e.g., "Bird flight arose in ground-running dinosaurs that used their wings for lift").

Use of the DMap brings key benefits for student learning and intellectual development. Students become more proficient in argumentation as a result of learning to recognize when they have developed arguments supported or opposed by relevant evidence. By posing genuinely controversial claims, as conflicting hypotheses in the scholarly literature or as conflicting points of view on public policy issues, the DMap trains students to construct an advanced form of argumentation in which they must understand differing perspectives, put forward and support reasons for both sides, and reach a reasoned conclusion based on arguments and evidence. The ability to think dialectically and evaluate arguments and evidence is a core element of critical thinking and a vital skill for an engaged citizenry.

Researching and summarizing the reasons and evidence that support two differing points of view and reaching a reasoned conclusion requires students to fully engage with academic and public policy controversies in science. At the beginning of their university careers, many STEM students see science as a body of facts. The DMap assignment supports STEM students in moving from an approach in which there are only right and wrong answers to one in which the student's role is to select an appropriate approach and evaluate solutions to problems (Perry, 1970).

The *Evolution* course, which is an upper division course required for all students completing a Biological Sciences major, deals with processes causing genetic change in populations and major evolutionary trends over geological time. In the case considered here, the course was delivered online. The DMap was introduced with the intent of training students in argumentation, while reinforcing key course concepts. Each student in the course argued for or against one of three claims:

- Evolution is a gradual process.
- Natural selection can favor traits that lower individual fitness but increase group fitness.
- *Homo sapiens* and *Homo neanderthalensis* belong to the same species.

Each student's DMap was required to include three pro and three con reasons, each with relevant supporting/opposing evidence and suitable warrants, and a conclusion that briefly explained the reasons and evidence that support their claim. Students used relevant scholarly articles and could also cite their textbook, other books, popular articles, or web resources. Students could submit draft DMaps a week before the due date if they wished to receive formative feedback.

94% of students in the course rated their knowledge of the basics of argumentation as low ("I know little about the basics of argumentation") or medium ("I know some, but not all, of the key argumentation components"). To familiarize students with the components of argumentation (reasons, evidence, warrants), students were introduced to the DMap tool in a one-hour online DMap tutorial. After a brief presentation on how to map an effective dialectical argument, students worked on a sample DMap, addressing this genuinely controversial claim: "Trophy hunters should be permitted to kill polar bears in Canada's Arctic." Students were provided with information extracted from scholarly papers, government statements, advocacy websites, and interviews. They were asked to develop one pro and one con reason, each with one piece of evidence and a suitable warrant. Instructors provided feedback on these argument components. Half of the students agreed or strongly agreed that DMap training prepared them well to build their own DMap, while most of the remainder (44%) were unsure.

The biological science students had positive responses to the DMap assignment. They described the DMap tool as having a user-friendly interface that is intuitive and easy to use. 75% agreed or strongly agreed that instructors should use DMapping to teach argumentation, while many agreed or strongly agreed that the skills they learned through DMapping can be used in their other courses (82%) or in their lives (68%). 92% of students agreed or strongly agreed that addressing claims with the DMap is a good way to learn about a topic. Comments gathered from students illustrate this perceived benefit:

> "I really had to think thoughtfully about the materials I read, and then separate my thoughts into pros and cons. This really helped to integrate the knowledge I learned."

> "Finding and providing arguments and rewording them in my own way helped me learn the concepts."

> "I really liked that they made me think deeply about the two arguments, especially since there wasn't a correct answer."

Case 2. Computing Science – Collaborative Argumentation for Information Literacy

Exploring Computing Science is a lower division course designed for SFU students who are *not* Computing Science majors. It exposes students

to basic programming principles, explores fundamental ideas in computer science, and examines the impact of computational thinking on modern society. We connected the DMap assignment with course content on machine learning algorithms and the widespread use of big data. Additionally, we required that students complete their DMaps in collaborative groups.

In this case, which involved collaboration between the course instructor and an academic librarian, we used the DMap assignment as a vehicle for information literacy instruction. In an era of information abundance where misinformation over social media platforms abounds, strong information literacy skills and dialectical argumentation are complementary academic skillsets. Dialectical argumentation benefits students who are learning concepts (Asterhan & Schwarz, 2007; Dwyer et al., 2013; Nesbit et al., 2019), but less is known about how to support students, who are not subject experts, in finding sources that frame the debates within various academic disciplines. We present a strategy for scaffolding information literacy instruction in the context of a DMap assignment.

We developed a unit of interconnected assignments in three different sections of the course. To begin, students read a short passage from Noah Yuval Harari's bestselling *21 Lessons for the 21st Century* (2018, pp. 50–56). He makes provocative statements about the impact that Google and big data have had on our ability to conduct research and make decisions. From this passage, we selected the following claims:

- Google has diminished our ability to search for information.
- Google's top search results are "the truth".
- AI will eventually make better major life decisions (e.g., who you marry, what you study) than you would have made yourself.
- Big Data algorithms: they have lots of glitches, but we have no better alternative.

As Google, AI and big data are ubiquitous in our daily lives, researching these claims also requires students to critically self-reflect on their impact and their own research processes.

To implement the unit's information literacy component, we adapted two open educational resources that address the challenges students have finding and evaluating sources (Bloom & Deyrup, 2015; Head & Eisenberg, 2009; Wineburg & McGrew, 2017). We began with the SIFT evaluation method (Caulfield, 2017). SIFT stands for Stop, Investigate the source, Find better coverage, and Trace claims to the original source. This method quickly and effectively provides students with a strategy to assess a source's credibility, and an initial pathway to find trusted sources. For source discov-

ery, we implemented the Information Needs, Types, and Sources curriculum developed by Wilkinson (2016). It asks students to find five categories of resources on their topic: background information, current events, statistics, opinions, and research.

We executed the unit in several stages. Students first completed online tutorials on the SIFT method and how to find sources from the five categories. They then chose one of Harari's claims to research and compiled a bibliography of sources, one from each category. At least one source had to disagree with the other sources. To analyze and assess students' research process, we also asked students to write a passage of 200-500 words describing how they found and chose one or two of their sources.

We created a rubric to assess students' bibliographies and reflection passages. Students were graded on having completed the bibliography with an appropriate source and a correct citation. We also looked for evidence of their search persistence, how they applied the SIFT method, why they trusted the sources they chose, and for clear organization.

After completing the bibliography and reflection assignment, students formed groups and completed a single DMap relying on the sources they found in the information literacy assignment. They had been trained in using the DMap by following a self-guided tutorial and completing a practice DMap in class. The DMap exercise aimed to stimulate discussion among group members in which they shared their research findings and negotiated a common claim and relevant evidence.

The DMap rubric included the following criteria:

- At least 3 reasons, both pro and con
- At least 1 piece of evidence per reason
- Correct citation and warrant for each piece of evidence.
- Cohesion and clarity for reasons, evidence, and warrants
- Clear and fulsome conclusion

We awarded points for both the whole group and individual efforts. Every group member had to "own" a reason with their name attached, which corresponded with one row in the rubric. The entire assignment was worth twenty-two points, two of which were for individual effort.

Students were generally positive about the information literacy / DMap unit. One student commented, "I found the SIFT readings and [bibliography] to be tiring and time-consuming, but I realized on the DMap assignment that I had become much more efficient after having acquired the research skills and familiarity with research tools." Another appreciated the chained nature of the assignments: "The sequence of these three assign-

ments should be offered to students in other disciplines as it is quite helpful in courses that involve research, and ways through which arguments can be properly organized such as the DMap." Another said, "[The assignments] allow students to understand the relevance of the types of sources, and it gives students a chance to apply that knowledge by looking for sources individually and through the DMap." One student, however, found that the DMap was difficult to complete in an online collaborative environment.

We are encouraged by the positive feedback from students who received instruction on source discovery and evaluation techniques preceding their group DMap assignment. This approach is suitable for students who lack prior knowledge of the subject in question. When they are asked to primarily cite scholarly sources, they often feel frustrated and intimidated. The bibliography instructions required students to find a variety of source types, which helped them find multiple points of view. Furthermore, we also believe that the group DMap assignment stimulates discussion about the content of the claim, the evidence presented in the sources, and students' research processes. While further research on combining information literacy instruction with the DMap is required, this approach is a good starting point.

Case 3. Educational Psychology – Managing the Cognitive Load of Argumentative Writing

The *Introduction to Educational Psychology* course at SFU is designed for entry-level students and serves as a prerequisite to several higher-level undergraduate education courses. The course introduces students to educational psychology theory, research, and application. It covers topics such as cognitive development, social development, learner differences, achievement motivation, learning sciences, and educational assessment. This case summarizes the experiences of two instructors, one who taught a face-to-face section and another who taught online sections.

The DMapping assignment served as a prewriting task. Each student developed a DMap which they used as a foundation for writing an argument essay. The primary purpose of the argumentation component in the course (DMap plus essay) was to promote understanding and reflection about educational psychology topics. There is evidence that argument-focused learning activities can lead to enhanced conceptual understanding of argument-relevant information (Wiley & Voss, 1999; Nussbaum & Sinatra, 2003; Sampson & Clark, 2008). A secondary purpose was to develop students' ability to construct arguments and think critically.

Undergraduate writing assignments often expect students to choose their topics and theses through research with bibliographic sources. Bibliographic research is itself a complex task that can be challenging for many undergraduate students (Head & Eisenberg, 2009). Our experience suggests that when students do poorly on argumentative writing assignments, it is because they are overwhelmed with the challenge of coordinating three difficult task phases: a) bibliographic search, b) argument development, and c) expressing the argument as written text. Because bibliographic search precedes the other phases (although it also co-occurs with them in later stages of the process), students often spend a disproportionate amount of time in the information search phase and may not start on the latter phases until the assignment deadline is almost upon them. Consequently, over the series of writing assignments they experience in their undergraduate programs, they may never have allocated enough time to fully develop arguments and express them in writing. While Case 2 illustrated how DMapping can be combined with an emphasis on teaching information literacy and bibliographic research, this case addressed the issue of cognitive overload by reducing the complexity of the bibliographic search phase. Students were provided with links to 250 highly readable one-page summaries of educational psychology research studies on the *Science Daily* website. The titles of and links to the articles were listed on a webpage available through the LMS. The article summaries were selected by the instructors for the quality of the reported research and the relevance of the research to the course lectures and textbook readings.

For the DMap and essay assignments, each student was asked to construct a main claim or thesis which could be supported or opposed by *Science Daily* summaries provided by the instructor in the LMS or, in the on-campus section, found by the student on the *Science Daily* website. Examples of thesis statements constructed by students are:

> "Teenagers should be discouraged from playing violent video games."
>
> "High school students would benefit academically and socially from nap time during school hours."
>
> "Usage of social media increases narcissism."
>
> "Experiencing failure is beneficial for students' academic motivation and self-efficacy."

The assignment requirements for both the on-campus and online sections presented information search conditions that were much less cognitively demanding than students would typically experience when researching full-text sources with a bibliographic database.

Our experience is that reducing the load of the bibliographic search phase, while helpful, still leaves students with the difficulty of coordinating the task phases of argument development and writing which students may not perceive as having distinct goals and products. Our solution was to separate the two phases into two related assignments. In the DMap assignment (14% of the course grade), students generated a topic and thesis using the Science Daily sources. They were asked to submit a full DMap with a thesis, two pro reasons, two con reasons, evidence and warrants supporting each reason, and a conclusion. After students received scores and feedback on their DMaps, they were asked to write and submit essays (30% of the course grade) that incorporated a revised version of the argument shown in their DMap. By having students focus on argument development in the first assignment and writing on the second assignment, we expected that the course would more effectively support their learning of both these key skills.

Prior training in the components of arguments (e.g., counterarguments and rebuttals, warrants) and use of the DMap tool is crucial to maximizing benefits students receive from completing the DMap assignment. In the on-campus section, this was provided in tutorial sessions led by teaching assistants. Students in the online sections were asked to view a video prepared for the course that explained the argument components needed for the assignment and how to construct them using the DMap tool. They were also provided with a resource link developed by the university's writing center which explained argument structures. The instructor of the online sections still found it necessary to schedule real-time online meetings with some students to teach argument structures and their role in writing composition.

The students' questionnaire responses were generally positive and very similar to the aggregate responses presented later in this article. Most preferred DMapping to writing as a mode for expressing arguments in course assignments, and most believed that DMapping helped them learn the relationships among course concepts and think more deeply about course readings. One student stated in a post-course interview that "The DMap was easy to navigate and easy to use. I liked its simplicity; it didn't cause me to become overloaded. It motivated me to keep writing, so after every step, I knew I could proceed onto filling the next section. It was handholding me through the way. Based on the feedback I received from the DMap, my final essay was slightly different, but it was easy to convert the DMap to a full es-

say." The only significant negative experiences reported by students related to several occasions when the DMap server was unavailable for technical reasons.

Due to its positive reception by students, and our observation of the focus it brings to the argumentation process, we are retaining the DMap assignment in current versions of the *Introduction to Educational Psychology* course. We are also planning alternative ways of using DMapping in this and other courses we teach. Analytical reading is an important subject-specific skill that can be developed in the context of a writing assignment (Qin & Liu, 2021), or as a stand-alone assignment. We can imagine having students select a research article in educational psychology and submit a DMap that outlines its argumentative structure. Such an assignment may help coach novice writers and teach them basic summarization and paraphrasing skills, training them to be independent readers and writers.

Case 4. Psychology – Promoting Construction of Balanced Arguments

The *Introductory Psychology I* course at BCIT is a first-year undergraduate course taken as an elective by some students and by others as a requirement for programs such as accounting, nursing, interior design, and business studies. The course introduces students to topics such as memory, learning, intelligence, social behavior, psychopathology, and psychotherapy. An important learning outcome of this course is understanding controversial topics in psychology. In addition to developing students' ability to find credible sources and think critically, argumentative writing on controversial topics is effective in enhancing students' learning-related motivations such as curiosity and self-efficacy (Meral et al., 2022). In prior offerings of the course, students' argumentative writing demonstrated the same weaknesses reported by previous researchers (Asterhan & Schwartz, 2007; Wolfe et al., 2009). Specifically, students found it difficult to weigh the strength of argument components and to construct and rebut counterarguments. Also, students who had less experience with argumentative writing were unlikely to present warrants for the evidence they had provided.

The DMap tool was deployed in the course with the goal of enhancing students' skills in argument writing and their engagement with controversial topics. We also anticipated that DMapping would help students transfer argumentative skills to their lives beyond the classroom. Students who understand the structure and function of argumentation and fact-based reasoning are better able to assess information critically, contribute constructively to

workplace decisions, and fully participate as responsible citizens in a democracy (Liu et al., 2024).

As a preliminary step toward writing argument essays, students were assigned to construct DMaps, each of which was to include two pro and two con reasons. All students were assigned to argue the same claim (in this case posed as a question): "Should use of marijuana be legal in British Columbia?" They were directed to find credible resources in recommended bibliographic databases.

Each of the cases reported in this article describes how instructors incorporated the DMap tool in a learning design with the intent of resolving specific instructional issues. In this case, the instructors' goal was to explore how students' development of argumentation skills assists students in finding more credible sources and constructing more balanced and persuasive arguments. The instructors also wanted to observe whether students could easily convert the DMap into an essay by adding an introduction, transition phrases, and an extended conclusion.

The students' comments in post-activity semi-structured interviews describe how they experienced their work with the DMap. Students' initial perception of the DMap tool was generally positive. One student said "the DMap tool looked interesting in that it was well-organized and it was easy-to-follow." Another student mentioned "the DMap guided my research and my writing along the way." Giving more detail, another said "the interactive DMap guided my thinking more since I was trying to look for how the reasons could counterbalance one another and could move the boxes around."

Students reported they had more confidence participating in a discussion on the topic, since they had weighed the strength of their arguments while building the DMap and could counter others' points in a discussion with directly opposing arguments.

More experienced students indicated that the DMap was particularly helpful when reading from multiple sources is required and when instructors expect to see more than four pro and con reasons. One student had used the DMap for an assignment in another course and said "I decided to use the DMap for this other course because there was too much to read and DMap not only helped me to get started with the assignment (guided my research before I began to work on the DMap itself), but also guided me throughout every time I felt lost in the midst of all the reading materials."

Some students suggested how the functions and usability of the tool could be improved. For example, 1) adding replacement text to prompt and remind students what needs to go inside each text box, 2) enabling a text format download of the DMap which would make transforming it to an essay more convenient, and 3) adding an introduction box, as students pre-

ferred to have every component of a complete essay in a self-contained platform.

Overall, it seemed that DMapping was useful as a prewriting tool and, because of its interactive format, guided students' thinking. It led to more balanced arguments by prompting students to find relevant sources from both sides of an issue. Judging from their comments, students appreciated that argument components could be moved and re-ordered within a DMap, thus allowing for an arrangement that was closer to how they wanted to structure the argument in their subsequent essay.

Case 5. English as a Foreign Language – Developing Argumentative Writing in English

This case involved two sections of a *College English I* course open to first-year undergraduate students attending a public comprehensive university in China. The participating students were enrolled in a wide range of degree programs and were required to take the course to develop general English skills, including vocabulary, reading, writing, listening, and English-Chinese translation. One of the key learning goals is English argumentative writing, as this writing genre is often evaluated in English proficiency tests (Lu & Swatevacharkul, 2021; Yang, 2022).

Writing an argument essay requires an understanding of the essay topic, and the ability to argue for one's position using appropriate language (Jumariati et al., 2021; Liao & Liao, 2022). It is a challenging task for English as a Foreign Language (EFL) students and is made more difficult by the fact that many undergraduate instructors lack skills in teaching argumentative writing (Majidi et al., 2023; Yang, 2022; Zhao et al., 2023). In this case, which presents previously unpublished data from research by Liu et al. (2024), we explain how the DMap tool was used to support an in-class argument visualization activity as a supplement to instructor-led presentations, and we assess the potential role of DMapping in addressing the challenge of teaching argumentation to EFL students.

First, the instructor gave a 15-minute presentation that explained the essential components of argumentation (i.e., claim, pro reason, con reason, supporting evidence, opposing evidence, warrant, and conclusion) and the key features of the DMap tool (e.g., how to link opposing arguments). Then, the students engaged in a DMapping activity that lasted about 25 minutes. They were instructed to read a passage about wind power and construct a DMap to argue whether wind power should be widely used. For reasons similar to those presented in Case 3, the wind power passage was provid-

ed as the source to avoid the difficulties entailed by information search and help students focus on argumentation as a key learning outcome.

As a follow-up to the argumentation tutorial and the DMapping activity, two in-class essay exercises were assigned over the next two weeks. For essay exercise 1, the students were asked to write a brief essay on the same topic (wind power) they used for DMapping. There was no explicit instruction on which components, or how many of each component, should be included in the essay. Compared with the other sections of the same course, the section that used DMapping wrote significantly longer essays and gave more pro and con arguments.

For essay exercise 2, the students were invited to write a brief essay on a different topic: whether or not universities should increase use of computer technology for student learning. Since most students knew this topic well, no reference reading materials were provided as the basis of argument construction. This allowed us to more effectively measure the transfer of argumentation skills acquired. The transfer essay scores revealed DMapping contributed to an enhanced awareness of attending to opposing perspectives when defending a claim. 51% of the students in the course section with the DMapping learning activity included all three key argumentation components (e.g., pro argument, con argument, and rebuttal) in their essays, while only 38% of those in the comparison sections did the same.

In their questionnaire responses the students said they saw DMapping as beneficial for inducing deep processing of new information and motivating active learning of argumentation. Interestingly, most students (68%) agreed it was easy to use, but about 54% indicated low self-efficacy in using the DMap.

To better understand the benefits and challenges of studying with the DMap, six students were invited to a focus group interview. The students agreed that using the DMap as a pre-writing tool made it easier and quicker to put together an essay, which may have explained why the DMappers tended to write longer essays within the same amount of time. For example, they commented:

> "Its interface kept reminding me of the importance of including con reasons."

> "After completing [the DMap], I found it easier to get an idea where to start and what to do next."

> "The best thing for me is it helped me get the essay done more quickly."

Regarding the challenges of DMapping, students mentioned their unfamiliarity with the DMap tool and insufficient understanding about some of the argument components, as shown below:

> "I don't know if I'm using [the DMap] in the right way."

> "I came up with one [counterargument] but I didn't know where to add it in my essay. Then I deleted it because it may impact my grade."

> "I forgot the difference between evidence and warrant."

In summary, DMapping was successfully deployed in an EFL classroom in China. The students' argumentation skills measurably improved, despite using the tool only once. The pedagogical impact might have been more salient if students were given multiple DMapping activities. Future research should focus on how to foster students' self-efficacy in using the DMap and inclusion of rebuttals in argumentation. Formative feedback from peers or instructors, as used in Cases 1 and 2, would likely have further enhanced the learning outcomes.

Student Attitudes Toward DMapping

In addition to the 5 cases, in this section we present results from a questionnaire administered to a larger group of students, many of whom had experienced DMapping in courses outside the cases we have presented. To assess students' attitudes toward the DMap tool and DMapping as a learning activity, we constructed a 28-item instrument, which underwent rigorous review and refinement by a team of educational researchers and instructors with extensive experience teaching argumentation as a key learning objective. The questionnaire was designed to investigate students' beliefs about the efficacy of DMapping for learning course content and argumentation. It also asked about the convenience and usability of the DMap tool. Students responded on a 5-point Likert scale (1 Strongly disagree; 2 Disagree; 3 Not sure; 4 Agree; 5 Strongly agree).

The questionnaire was deployed in 7 courses delivered between Spring 2021 and Fall 2021. Questionnaire data were gathered from 426 students who consented to participate in the research. Six students, each of whom missed a single question, were removed to produce a sample of 420 participants. The internal consistency reliability of the questionnaire data was high (Cronbach's $\alpha = 0.95$).

Overall, the responses to the questionnaire were supportive of the continued use of DMapping learning activities and the DMap tool. As a full analysis of the questionnaire data is beyond the scope of this report, we present the results for 10 selected items shown in Table 2. The selected items and their results are highly representative of the full questionnaire. The table shows Proportion of Agreement (PA) and other indices of students' responses.

Table 2

Student Responses to Selected Questionnaire Items (N = 420)

	Mean	*SD*	*PA (%)*	*RAD*
1: DMapping led me to think more deeply about what I was reading.	3.65	0.94	67.1	4.7
2: Making an argument is a good way to learn about a topic.	4.15	0.69	90.4	29.6
3: DMapping made me more enthusiastic about learning the course content.	3.23	0.97	43.9	1.8
4: Using the DMap helped me learn how to argue well.	3.55	0.95	60.2	3.9
5: Instructors should use DMapping to teach argumentation.	3.99	0.90	78.9	14.0
6: I would prefer DMapping to essay writing as a method of assessment.	3.94	1.18	73.7	4.8
7: I find it easy to use the DMap tool.	3.89	0.99	78.9	5.7
8: Making an argument in DMap is quicker than writing the argument as an essay.	4.09	1.03	80.0	6.7
9: I could teach a classmate how to use the DMap if they were stuck.	4.11	0.82	85.7	17.4
10: DMapping is an efficient way to prepare an argument.	4.10	0.75	86.6	23.0

Note: PA is the proportion of agreement (the percentage of students who either agreed or strongly agreed with the item). *RAD* is the ratio of agreement over disagreement (*PA*/*PD*). The numbering of items presented here does not correspond to the order of items presented to the respondents.

The responses to Q1 and Q2 show that most students believed DMapping and argumentation are effective ways to learn about the content of a course. In contrast, the result for Q3 indicated only mixed support for the idea that DMapping increased their motivation to learn the course content. Of the 28 items in the questionnaire, Q3 was the least supportive of continued use of DMapping. The responses to Q4 and Q5 show that most students believed DMapping is an effective way to learn argumentation. The remaining items in Table 2 relate to the ease of use and convenience of the DMap tool, and DMapping as a mode of expression. The responses to these items align with student comments cited in Cases 3, 4, and 5. They suggest that students tend to prefer DMapping to writing argument essays, likely because they find it is a relatively convenient and efficient way to express an argument.

Discussion

The five cases presented in this paper were conducted in authentic postsecondary classrooms across diverse disciplines. The findings are in line with those of previous studies that well-designed argument visualization activities effectively engage students in cognitive processes leading to enhanced learning outcomes (Davies et al., 2021; Dwyer et al., 2013; Indrawatiningsih et al., 2020; Jumariati et al., 2021; Liu, 2020; Rathkopf, 2024). DMapping, as an example of argument visualization, can be flexibly integrated into curricula to reinforce the learning of argument structure and promote the acquisition of advanced argumentation skills (Nesbit et al., 2019; Niu, 2016; Pakdaman-Savoji et al., 2019). Echoing prior research (Carrington et al., 2011; Chiang et al., 2016), student feedback demonstrates their enjoyment and perceived effectiveness of incorporating argument visualization such as DMapping as an instructional activity.

Many students have difficulty making strong arguments primarily because their argument schemas are insufficiently developed (Liu et al., 2024; Reznitskaya et al., 2001). The DMap is a cognitive tool that visually and concretely represents a functional argument schema, and thereby assists students in effectively analyzing, evaluating, and constructing arguments (Jonassen & Reeves, 1996; Nesbit et al., 2019; Niu, 2016). The students participating in this study generally had limited prior knowledge about argumentation, which might result in significant cognitive load as they navigated the complexities of developing arguments involving the processing and manipulation of information from multiple sources. In such circumstances,

the cognitive affordances provided by the DMap may prove essential. The DMap could function as an externally distributed memory by recording and visualizing the development of students' arguments (e.g., which components and connections are completed and which areas need further work), enabling them to allocate more mental resources to intricate aspects of argumentation that might otherwise exceed their capacity, such as evaluating the strength of each reason provided and refuting opposing arguments (Lajoie, 1993; Liu et al., 2024). It is important to note that none of the cases presented in this study assigned multiple DMap assignments throughout the term. According to Pakdaman-Savoji et al. (2019), students can be expected to benefit more from repeated engagement with the DMap than from a single usage, particularly when the objective is for students to internalize the argument schema represented by the DMap and argue effectively without external aids.

Lessons Learned

In this section, we present ideas for implementing argument visualization in undergraduate education drawing from our five cases and the broader survey of student attitudes. Although our experience is in teaching with DMaps, the ideas presented here are likely applicable to teaching and learning with other argument mapping tools.

Training. All the instructors recognized the need for students to be given DMap training prior to undertaking their first DMap assignment. Active learning sessions with formative feedback are ideal, and for some students they may be necessary. In the one instance where training was provided to a class in the form of a tutorial video (the remote learning section in Case 3), the instructor found it necessary to videoconference with some individuals or small groups to answer questions and address gaps in understanding. Despite the time and effort required, training in argument visualization need not be regarded as an add-on time cost because we found most of the tutorial time focuses on teaching argument structure rather than the specific technical features of the tool.

Counterargument and rebuttal. We found that, before engaging with the DMap, many students were not confident in addressing genuinely controversial issues. Science students, notably, often consider a scientific topic as a body of facts. DMap assignments have been found effective in helping such students recognize the value of understanding contrasting perspectives on scientific hypotheses or public policy issues, formulating arguments on

both sides, providing relevant evidence for these arguments, and reaching a reasoned conclusion. As mentioned in Case 5, DMapping seems not effective in prompting completion of the claim-counterargument-rebuttal chain. Modifying the DMap interface to more directly prompt rebuttals and designing assignments to provide scaffolded practice of rebuttal would be beneficial.

Evidence and warrants. Evidence refers to the specific facts, data, research results, examples, expert opinions, or other information used to support a claim, whereas warrants are the justifications that connect the evidence to the claim (Toulmin, 1958). In DMaps, warrants provide a logical bridge between evidence and the reason to which it is linked. Among the key components of DMaps, only the warrant is unfamiliar to many students and instructors. Qualitative data collected from Case 1 and Case 5 showed that students often confused 'evidence' with 'warrant' and found it difficult to write a suitable warrant to elaborate on the logical connection between a piece of evidence and the pro or con reason it is linked to. In training sessions, it is necessary to provide examples to reinforce the role of warrant in argumentation and how it relates to the evidence provided. Teaching students the appropriate use of warrants in argumentation is an essential feature of preparing students to construct DMaps.

Benefits of stand-alone argument map assignments. Although in most of our cases instructors required students to write an essay (or in Case 2, a bibliography) related to their DMaps, in Case 1, students submitted only DMaps. This type of stand-alone argument mapping assignment may be preferable when the goal is to have students learn course concepts via argumentation or to develop critical thinking skills rather than writing skills. Additionally, as shown in Table 2, students reported that creating a DMap is faster than writing an essay about the same argument, and most preferred DMapping over essay writing. In our experience, the clearer structure of DMaps makes them much faster to grade than essays. DMapping allows TAs to provide effective formative feedback, while also managing their workload (Irons & Elkington, 2021).

Developing information literacy. Argumentation motivates students to find credible sources. However, as noted in Case 3, students often struggle during literature searches and spend a disproportionate amount of time during the research process. This underscores the importance of information literacy instruction, where students learn strategies to efficiently and effectively find evidence that supports their arguments. Case 2 demonstrates a scaffolded approach where a librarian delivered the research skills component prior to students completing their DMaps. Students then transferred their

sources to the DMap as evidence. In this case, an essay was not required, but the library research skills students developed was presumed to benefit them in researching subsequent essay assignments.

Managing the intrinsic cognitive load of written argumentation. Using DMapping as a pre-writing tool can reduce the cognitive overload students would otherwise experience when completing an argument essay assignment that requires coordination of bibliographic research, argument construction, and writing (Meral et al., 2022). Although learning to use the DMap tool may add some extrinsic cognitive load, the net effect of introducing DMapping as a separate assignment was to prevent students from being overwhelmed by the complexity of the task. As shown in Table 2, students perceived the DMap interface as easy to use and efficient. Student comments cited in Cases 3, 4, and 5 supported the idea that students found the assigned essay easier to write after they had prepared the argument as a DMap.

In-class DMapping. Whether students are constructing argument maps individually or collaboratively, there may be advantages to having students engage in argument mapping activities during class time when the instructor is available to assist, as in Case 5. In addition to making the class more engaging, organized, and student-centered, it was observed that the EFL students benefited from in-class activities that induced teachable moments and meaningful dialogues on how to argue effectively with the DMap tool. If well implemented, in-class DMapping practice can strengthen and extend what students learned from the initial training session. Considering the importance of enabling iterated interactions with the DMap as a cognitive tool (Pakdaman-Savoji et al., 2019), it is helpful to expose students to multiple low-stakes in-class DMapping activities with access to just-in-time feedback and support. This approach is likely to boost students' self-efficacy in argumentation and direct their attention to argumentation as a process, rather than merely a product.

Based on our experiences teaching with the DMap and the key findings of the five cases, Table 3 lists suggestions on how to design and implement DMap assignments in undergraduate courses.

Table 3

Guidelines for Designing DMap Assignments

Phase	Key Considerations	Suggested Practices
Training	▪ Prior knowledge about argument structure ▪ Prior experience with argument visualization ▪ Tutorial delivery modality	For students proficient in argumentation, training could be as simple as providing an annotated example of DMap or a pre-recorded tutorial video. For students new to argumentation or argument visualization, the training session should include the following components, conducted consecutively: (1) Detailed instructions on the components of argumentation: Understanding terms like *warrant* and *rebuttal* can be challenging for many students, so additional explanations or examples are often helpful. (2) Introduction to the DMap tool and its features: In addition to demonstrating how to use the DMap (e.g., how to add a reason), it is beneficial to explain how each feature (e.g., rating the strength of reason and linking directly opposing arguments) contributes to effective argumentation. (3) DMapping exercise: For example, in Case 1, students are instructed to complete a simple DMap involving one pro reason and one con reason, each with one piece of evidence and a warrant. The instructor can provide a list of information as the basis for DMapping, allowing students to focus on argument construction rather than evidence search. The instructor should be available to provide just-in-time feedback and support. In-person or real-time interactions are recommended.

Phase	Key Considerations	Suggested Practices
Assignment Design	▪ Key learning outcome(s) ▪ Familiarity with the argumentation topic ▪ Proficiency in bibliographic search	If the learning outcome is associated with developing scientific thinking rather than writing skills, it may be preferrable to design the task as a stand-alone DMap assignment. If the learning outcome emphasizes other aspects like writing skills, it may be preferrable to set up a multi-part assignment, starting with DMapping as a prewriting activity followed by a separately assessed argument essay assignment centered around the same thesis. For further guidance on setting up either a stand-alone assignment or a prewriting activity with the DMap, please refer to the section titled *Using Visualization Tools to Construct Arguments*. If the argumentation topic is unfamiliar to students or demands extensive bibliographic research, it can be beneficial to provide students with a curated list of resources, as depicted in Case 3. This resource list assists students in constructing different components of their arguments without spending too much time on information search such that they can focus primarily on developing their argumentation skills and writing proficiency. A resource list may be particularly helpful for those less skilled in bibliographic search.
Assessment	▪ Feedback ▪ Grading rubric	For either standalone or prewriting assignments, students benefit from receiving formative feedback, which can be provided by the instructor or peers. Consider developing and disseminating to students a grading rubric to support both “assessment of learning” and “assessment for learning”. The rubric can outline the expected scope and depth of the work by specifying both quantity and quality expectations for each type of argument component (e.g., claim, evidence, warrant, and conclusion). Additionally, it can include evaluation criteria for other aspects of the assignment such as organization, coherence, mechanisms, and language use. The rubric detailing how points will be assigned for different argument components and other evaluation aspects can aid in grading assignments with greater efficiency and consistency.

Limitations and Future Research

Similar to other studies conducted in authentic classroom settings, this study faces challenges regarding internal validity and the generalizability of its findings to broader populations or contexts. In addition to collecting details about course settings and characteristics, it is beneficial to gather student demographic data, such as gender and age, which enable replication of the study and facilitates evaluation of its applicability to various instructional contexts.

There is abundant evidence that collaboration can boost student learning (Chen et al., 2018; Pai et al., 2015). Collaborative mapping likely offers significant added value beyond what students obtain from individual argument mapping assignments. Compared with essays, argument maps may be more conducive to collaborative construction because individual students can more easily add or edit components without being concerned with maintaining a consistent voice or writing style. While working on the DMap with peers, students are exposed to multiple perspectives and sources of information, which may provide more direct access to refutation and motivate them to be more selective in the process of argument construction. Such interaction and cognitive effort can potentially contribute to enhanced learning outcomes. Future research on collaborative DMapping should be undertaken to empirically test this assumption.

In addition to argument essays, exploring the role of DMapping in other types of assignments with less overt engagement in argumentation, such as science lab reports, could be of interest. Gouvea et al (2022) contended that lab reports entail a process of scientific thinking beyond simply filling in answers on a worksheet or recording findings to demonstrate a desired conclusion, as is often observed among students. The DMap offers a structured framework guiding students to systematically organize and evaluate the data gathered through observation or experimentation as the basis for evidence-based reasoning and conclusion development. Exploring strategies for integrating DMapping into science lab reports presents a promising direction for future research.

This paper showcases the use of argument mapping aided by the DMap tool in five postsecondary courses spanning diverse disciplines, including evolutionary biology, computing science, educational psychology, psychology, and English as a foreign language. Exploring the application of DMap in additional domains such as history, medicine, and business, as well as in secondary classrooms, holds promise for further research and practical implementation.

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