Designing and testing visual representations of draft essays for higher education students

Conference or Workshop Item

Designing and Testing Visual Representations of Draft Essays for Higher Education Students

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ABSTRACT

This paper reports the findings of an empirical investigation, which set out to test a set of rainbow essay exercises. The rainbow diagrams are pictorial representations of formal graphs that are derived automatically from student essays. They were designed to allow students to discover how key concepts in a well written essay are connected together. The students would then be able to compare a rainbow diagram of their own essay with a good essay and make changes to it before submission to their tutor. However a trail was undertaken with academics, teaching and learning staff, doctoral students at the Open University of Catalonia and the Open University UK, before implementation into the web application known as Open Essayist. All the participants from each University completed the exercise correctly. This was a surprising finding as we expected participants to experience some difficulties, as previous visual representations we piloted. All the participants remarked that they had learnt a lot about the structure of good essays and more importantly how clear the role of the conclusion played in a well-constructed essay. This type of representation made this explicit and they would be able to see quickly if a second draft had improved. The users also mentioned that the rainbow diagram representations could be used as a generic essay feedback tool. It could be used across subject domains, a hypothesis worthy of further investigation.

Categories and Subject Descriptors

K.3 [**Computers and Education**]: General

General Terms

Measurement, Performance, Design, Experimentation.

Keywords

Designing, testing, visual representations

1. INTRODUCTION

One of the grand challenges for Learning Analytics is to present the complex underlying analysis of data in a form that can be readily understood by the user [1]. By this we mean that learners are enabled to move forward in their studies by using the information obtained from the analysis. This type of feedback has been described as "Advice for Action" [2].

In our case we wish to use the analysis to promote self-reflection which will enable the user to enter into a self-reflective discourse with the automatic computer feedback. However the visual representation could also open a discourse between the tutor and the student or among peers studying the same module.

The analysis of large data sets and even the procedures through which they are constructed has not played a large role in educational studies. The history of this work illustrates that it is based in the sociology of statistics [3]. However tables, charts and other forms of representation according to [4] have "always involved the world of imagination". Therefore good visual representations should be able to capture the user's imagination in order to assist understanding together with creating a discourse around this new comprehension of the data.

OpenEssayist is a system that has been built to assist students in higher education to understand the weaknesses in their draft essays by exploiting automatic natural language processing analysis techniques. A real challenge for the OpenEssayist project team has been to design the system to give meaningful, informative, and helpful advice for action. In recent trials [5] it became clear that students were not aware of how the sentences were connected in particular essay graphics used in OpenEssayist to date. More importantly, they did not comprehend how the pattern of connections varied between an excellent essay and a poor one. Understanding these patterns has the potential to assist students to improve their essays in any subject domain if it can take the form of a generic visualization. This paper reports the findings from an empirical study that set out to test whether a type of visualization we refer to as a 'rainbow diagram' could convey this information to users within the OpenEssayist system.

2. THE ROLE OF VISUALISATIONS AS A TOOL FOR THINKING

One way to approach thinking is to describe it as a process that happens when people are working within a set of social networks and are using a suite of cognitive tools. This type of activity has been described [6] as sitting within cognitive systems theory. Visualization has a prominent role within this field of investigation. This is not surprising because we obtain more information through the eyes than through all our other senses put together [7, 8]. However, what is of real interest about visualizations is that they can promote thinking and that they can not only help individuals to identify patterns in a set of data, but also help them to discover emergent properties that could not have been originally predicted. This was the key to our research when we were seeking to identify a set of visualizations for the OpenEssayist system.

Visualizing information has been investigated for many years [9, 10]. It has moved beyond the scientific visualization of physical phenomena to the visualization of different types of information including sound, video and text. Visualizing structured information has been tackled since the 1980s [11, 12]. However free-text visualizations are still problematic to produce: so much information is available that it is often difficult to analyze and to see the patterns that are emerging from the data. Illustrating the connectedness of the concepts in an essay with a spatial representation that can be interrogated by the user could more enlightening and informative than just offering another form of textual output as feedback. However, the visual representation must not be something that cannot be understood by the user.

Another issue that needs attention is whether the user requires training in order to interpret pictures. Kennedy [13] together with [14] and [15], have reviewed this evidence and argue that people can interpret pictures without training. The question is still open, however, as to how diagrams are able to represent concepts unambiguously and as [6] warns; we should not understate the role convention plays in the understanding of any representation.

Data visualizations do not usually represent real-life scenes, for example, a high school text book drawing of light passing through the structures within the eye does not look like the actual phenomenon. In this scenario we are introduced to stylized elements that assist with data interpretation and we have to learn how to recognize and draw these types of physics diagrams. Another convention adopted in visualizations the use of straight lines to connect entities. We have adopted this in the rainbow diagrams in order to assist with feedback on student draft essays. We have adopted the hypothesis that users will need training in order to gain full benefit from these sorts of visual representations.

3. OPENESSAYIST

OpenEssayist has been developed as a web application and is composed of two components. The first component, EssayAnalyser, is the summarization engine, implemented in Python with NLTK[1] [16] and other toolkits. It is designed as a stand-alone RESTful web service, delivering the basic summarization techniques that will be consumed by the main system. The second component is OpenEssayist itself, implemented on a PHP framework. The core system consists of the operational back-end (user identification, database management, service brokers, feedback orchestrator) and the cross-platform, responsive HTML5 front-end.

The flow of activities within the system can be summarized as follows. Students are registered users and have assignments, defined by administrators, allocated to them. Once they have prepared a draft offline and want to obtain feedback, they log on to the OpenEssayist system and submit their essay for analysis, either by copy-and-pasting or by uploading their text document. OpenEssayist submits the raw text to the EssayAnalyser service and, once finished retrieves and stores the summarization data. From that point on, the students can then explore the data at their own pace. Using the various external representations available to them, they can follow the prompts and trigger questions that the Feedback Orchestrator generates from the analysis and can start planning their next draft accordingly.

This rewriting phase takes place offline, the system simply offering repeated access to the summarization data and feedback, as a resource, until the students are prepared to submit and explore the summarization feedback on their second draft and on subsequent changes between drafts. This cycle of submission, analysis and revision continues until the students consider their essays are ready for summative assessment. A major challenge is to provide feedback to the student that can be acted upon to improve the draft essay. In other words, to provide both textual and visual representations that can be used as cognitive tools.

4. MAKING GRAPHS FROM ESSAYS

The rainbow diagrams are pictorial representations of formal graphs that are derived automatically from student essays. Graph theory has been used in a very wide variety of disciplinary contexts. A graph consists of a set of nodes or vertices and a set of links or edges connecting them. (Some disciplines prefer the term 'network' to 'graph'.) Different 'centrality' measures are used to measure the relative importance or status of the nodes. The simplest centrality measure is 'degree centrality', which counts and compares the number of edges directly attached to each node. Some other centrality measures take into account indirect connections, rather than just those to the immediately neighboring nodes. These can be used to measure how similar a phrase or sentence in a text is to the whole of that text. This has been shown to be a good way of finding key words and key sentences in newspaper articles [17]. OpenEssayist uses graph theory to identify key sentences from within student essays. (OpenEssayist does much more than this [18], but discussion of its design is outside the remit of this paper.)

In the sentence graph, every sentence in the essay is represented by a node. Each sentence is then compared with every other sentence, and a value is derived representing the semantic similarity of that pair. That similarity value becomes a weight that attaches to the edge that links the corresponding nodes in the key sentence graph. We are currently using cosine similarity as the similarity measure. The nodes are ranked using [17] TextRank algorithm and key sentences are defined as the top 30 ranked sentences. Note that no domain knowledge or other expert knowledge or 'gold standard' model specific to a particular domain is used in the module's extraction of key words and key sentences. The rainbow diagram shows not only the key sentences of an essay but also every node of the sentence graph that has at least two edges, that is, every sentence of the essay that has some lemma (the canonical form of a set of words) in common with at least two other sentences.

[1] Natural Language Processing Toolkit, see http://nltk.org/

5. EXPLAINING RAINBOW DIAGRAMS

The following text about foxes, as shown in Figure 1 below, was used to illustrate how a piece of text is transformed into a rainbow diagram (see Figure 2).

Text (Extract from online FAQ about foxes)

Will the foxes in my garden attack my dog or cat?

This is extremely unlikely. ***2. Foxes avoid dogs, even small dogs, because many foxes are killed by dogs.*** So it is much more likely that your dog will attack the fox, not the other way round. Attacks on cats are equally rare: cats and foxes are roughly the same size, and cats are very capable of defending themselves against foxes. So it is hardly surprising that foxes generally give cats a wide berth and flee when threatened by a cat. Occasionally small kittens are killed, but this is rare. Keeping your cat indoors at night greatly reduces the chances of an encounter with a fox. ***8. There are also a variety of other benefits: cats kept in at night are healthier and live longer, and kill less of the local wildlife.***

Figure 1. Short text for illustration

The text in Figure 1 has the numbers 2 and 8 followed by violet and red text. This is because the text belonging to numbers 2 and 8 are shown in Figure 2 with the same colors in the sentence graph represented by Figure 2. The diagram illustrates how the key sentences are connected, which is an essential feature of the rainbow diagrams.

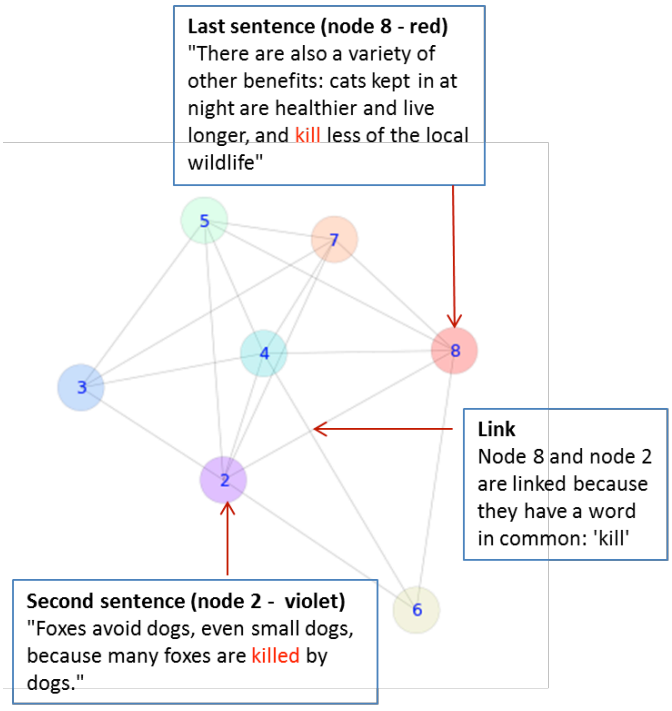

Figure 2. Sentence graph of short text

In the rainbow diagrams, each sentence of an essay is represented by a large colored dot (a node). The color of the sentences/nodes changes through an approximation of the rainbow spectrum in very small steps from violet (the first sentence of the essay) to red (the last sentence of the essay). Figures 1 and 2 illustrate. This means that sentences at the beginning of an essay show up in violets and those at the end of an essay show up in reds. Additionally, the nodes are partially transparent, and so when they are positioned on top of each other, the layered colors produce some brighter areas.

The lines that are drawn between the nodes are edges. Pairs of nodes are joined by an edge when the same word (or words) appears in both sentences. A node that has many links coming out of it and joining it to many other nodes is a sentence that has one word or more in common with all the nodes to which it is linked. (Each link may represent a different word, or the same word may be used repeatedly).

The algorithm that has been used to make these pictorial representations of the key sentence graph produced by EssayAnalyser is called the 'Fruchterman Reingold' algorithm [19]. This algorithm determines where the nodes of the graph should be placed in the diagram, (among other things) it uses the degree of connectedness of nodes to determine globally where they should be placed and it also places nodes near to other nodes to which they are connected. The most highly connected nodes are positioned in the middle of the picture, and the more sparsely connected nodes towards the outer edges of the picture.

In a well-structured essay as shown in Figure 1 above there is information in several paragraphs to support the statements made in the conclusion. You would therefore expect to see the reddest nodes near the centre of the picture, because they are highly connected to the rest of the essay (and therefore central), they are on top of each other (and therefore brighter), and they are at the end of the essay (and therefore red). Similarly, for the introduction, you might expect to see the brightest violet nodes near the centre of the picture. (It is slightly harder to see the bright violet nodes, because the earlier sentences are drawn first, and later nodes are drawn on top of them.). In a well-structured essay in which each paragraph discusses one main idea, you might expect to see nodes of similar colors near to each other in the picture.

6. THE EMPIRICAL STUDY

This small study set out to test a set of rainbow essay exercises which were designed by Debora Field. They were trialled with academics, teaching, and learning staff, doctoral students at the Open University of Catalonia and the Open University UK.

The study investigated the following questions:

1. Could the participants follow a set of explanations about the rainbow diagrams?

2. Could they complete a task that required them to match rainbow diagrams to particular essay types?

3. Did the participants consider the rainbow diagram feedback helpful in understanding the structure of a good essay?

4. Could they use this type of feedback to improve essay/paper writing?

6.1 Participants

Two groups of adults volunteered to take part in the study. The table below describes the participants. Twelve were from the Open University of Catalonia and twelve from The Open University UK. There were also twelve male and female participants.

Table 1. Participants from Open University in Catalonia and The Open University UK

Occupation	University
Professor of Teaching & Learning	OUC
Senior Lecturer Computer Science	OUC
Administrator	OUC
Professor	OUC
Ph.D student	OUC
Ph.D student	OUC
Ph.D student	OUC
Professor of Computer Science	OUC
Vice Rector	OUC
Administrator	OUC
Ph.D student	OUC
Ph.D student	OUC
Ph.D student	OUC
Senior Lecturer	OU UK
Learning & Teaching Officer	OU UK
Learning & Teaching Officer	OU UK
Learning & Teaching Officer	OU UK
Project Manager	OU UK
OU student	OU UK
OU student	OU UK
Senior Lecturer	OU UK
Professor	OU UK
Senior Administrator	OU UK
Course Administrator	OU UK

6.2 Methodology

The participants from the Open University of Catalonia completed the exercises from 6 – 10 May 2013. The group from the OU UK undertook the task during July 2013. Three of the participants were observed completing the task which they discussed after the exercise was completed.

Each participant was given a paper–and-pencil exercise which included a set of instructions about the meaning of the rainbow diagrams (very similar to the description of rainbow diagrams in Section 5 of this paper). The challenge part of the exercise can be seen in Figure 3. Examples of the four types of essay outlined in the exercise can be seen in Figures 4 to 8.

The Rainbow Essays Exercise contains some diagrams that you will be asked to categorise. There are several diagrams on each page of the exercise. Each diagram is a picture of a particular essay. There is only one picture of each essay, and so each page depicts several different essays. The design of the pictures has been automatically generated from the text of the essay by a computer program. The exact same program was used to generate all the pictures. The essays on each page have been grouped deliberately on the same page, because they are essays of a particular type. Your task is to decide which page corresponds to which type of essay. The essay types are as follows:

A. University student course assignment essay awarded a high grade

B. University student course assignment essay awarded a low grade

C. Stanford University Boothe Prize essay (source http://bootheprize.stanford.edu/essays.html)

D. Pretend essay manually put together (e.g., ten identical paragraphs)

Which type (A,B,C,D) matches which page (1,2,3,4)?

Figure 3. Rainbow essay exercise instructions

Figure 4. OU essay awarded high grade

The connectedness of the nodes as shown in Figure 4 means the essay is well constructed. The colors are important because the violet and red nodes which appear near the center of the diagram are close together. The key phrases associated with the introduction (violet nodes) are grouped close to the conclusion (red nodes). It is this pattern which represents an essay with a high grade.

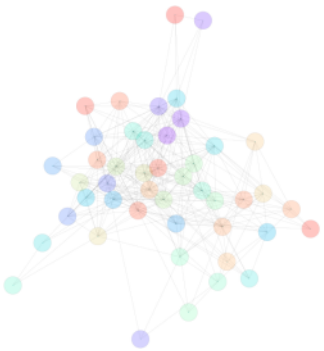

Figure 5. OU essay awarded low grade

The essay awarded a low grade. as shown in Figure 5 above, has the red nodes on the periphery of the diagram, whereas the violet nodes are in the center. The inference here is that the conclusion does not relate so well to the introduction.

Figure 6. Stanford University Boothe Prize essay

The prize essay as shown in Figure 6 has all the nodes very close together. The red nodes are very prominent in the center with the violet nodes close to them. The diagram shows clearly that all the concepts used to produce the argument for this essay are well connected. In other words, the thesis flows well and is an easy read. The colors are also more concentrated than in the other diagrams.

Figure 7. Pretend essay: 50 identical sentences

One way of testing whether the rainbow diagrams can represent a good essay was to construct a diagram from a fictitious piece of writing. When fifty identical sentences were analyzed by the rainbow diagram program, a representation with equidistant nodes appeared as shown in Figure 7 above. The colors are not more concentrated in one area as illustrated by Figures 4, 5 and 6.

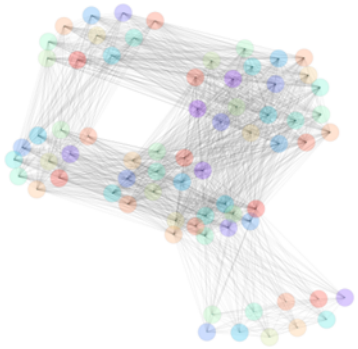

Figure 8. Pretend essay: 10 identical paragraphs

A diagram for a different type of pretend essay was also produced. This time the nodes did not appear within a sphere as the main representation was that of a rectangle with a plume attached to one of its corners. Again the color dispersion is different with violets and reds appearing in each corner of the rectangle and the plume.

All the examples illustrate the connectedness of concepts within an essay. The colors too portray how well the Introduction and Conclusion is aligned with the main body of the text. These were some of the main concepts we wished to convey to the participants.

6.3 Findings

All the participants from each University completed the exercise correctly as shown in Table 2 below. This was a surprising finding as we expected participants to experience some difficulties because previous visual representations we piloted [5] had not been understood. How did the participants begin to understand what the rainbow diagrams meant? In order to answer this question, we analyzed transcripts of the testing sessions of three participants who were monitored during the problem-solving process.

Table 2. Participants correct response to the identification exercises for the four different types of rainbow diagrams

	Correct responses for A	Correct responses for B	Correct responses for C	Correct responses for D
Females n = 12	12	12	12	12
Males n = 12	12	12	12	12

The strategy followed by the three observed participants was very similar and is summarized below. The participants:

- Carefully read the instructions
- Laid out each set of essay types side by side with the diagram from Figure 2
- First identified the pretend essays (see Figures 7 & 8)
- Secondly identified the Stanford University Boothe Prize essay (see Figure 6)
- Spent a longer time scrutinizing the university course assignment essays with high and low marks
- Identified essays with high marks (see Figure 4)
- Finally identified essays with low marks (see Figure 5)

One of the participants on her "talk-aloud" protocol explained how she decided which group of diagrams illustrated the student essays with the highest mark:

> *"One of the clues was talking about the way the color nodes, that the red ones are at the end. If they are a good connection with a good explanation for each paragraph. They should be connected together but the darker ones should be in the middle. But you see the color groups together so for me it automatically pulls my eye to this page because all the colors are closer together and more in the middle. So that would be the student course assignment essay with the highest mark."*

Another participant explained after he had completed the exercise:

> *"I mean I am all in favor of having different ways of interrogating text and asking students to think about where different parts are linked together. It's just getting them used to how to use it effectively. That's why completing the quiz was useful."*

Another reason given about why the rainbow diagrams were helpful was mentioned by the third female participant who took part in the "talk-aloud" protocol.

> *"You don't show me anybody's text. You are not revealing anyone else's essay. So students cannot plagiarize. But you are saying 'Look hang on, this is the way this essay connects together'. That's what telling a good story is about this linking."*

The final comment strengthens the argument that the rainbow diagram representations can be used as a generic essay feedback tool. It could be used across subject domains, a hypothesis worthy of further investigation.

All the participants remarked that they had learnt a lot about the structure of good essays and, more importantly, could see the role played by the conclusion in a well-constructed essay. This type of representation made this explicit and they would be able to see quickly whether a second draft had improved. More importantly when they read a weak essay from a module and matched it to its equivalent rainbow diagram, the participants were able to say how the weak essay could be improved and how they would expect the new rainbow diagram to look in the subsequent version of their essay.

The advantage of using the rainbow diagrams was described by the participants as making explicit the connectedness or lack of connectedness between the concepts attached to different sections of the essay. They felt this was more difficult to explain in words, for example, in typical tutor feedback. The diagrams also gave the participants more control over the changes they could make in the time left to them before the essay had to be submitted for marking.

All three participants had taken part in the OpenEssayist user testing and welcomed the addition of this type of representation to

the program. This was because they considered it would enable users to see what a good essay looked like and to ascertain quickly whether their drafts had improved. They also mentioned this approach was better than reading a "gold standard" essay since an example of this nature would probably conflict with University regulations and with the plagiarism issues associated with marked assignments.

All the OU Catalonia participants matched the essays correctly to the corresponding rainbow diagram. Likewise 10/11 participants from the OU UK matched the essays correctly on a first attempt. One participant did not complete the task correctly at first because she misunderstood the instructions. She then attempted the exercise again and obtained full marks.

7. CONCLUSIONS

The findings from the study were able to address the four research questions raised in Section 6.

1. The participants were able to understand the rainbow diagram explanations.

2. The training exercise was successful as all users were able to complete the matching task of essay type to particular rainbow diagram.

3. The users agreed that this type of representation in the context of the training assisted them in understanding the structure of a good essay.

4. They could see how to improve the connectedness of the concepts in their essay. This was assisted by the colors. They would not have been able to do this with a black and white representation.

Some of the advantages to visualizing data that provides constructive feedback to the learner has been summarized by [20]. These include:

- facilitating the learner's control over what facet of the visualization to explore in more detail and to drill down into areas of particular interest
- to provide a set of metrics that will be easy to understand
- to give the learner a set of different diagrams or views that can summarize the main points for exploration

We would like to add another advantage which is to provide a representation that can lead to a meaningful self-reflective or shared discourse.

Visualization spaces will change and improve and students will expect more flexible forms for the delivery of formative assessment or Advice for Action as found in OpenEssayist. Visual knowledge representation has a central role to play in this endeavor. Further research is required in understanding how visual representations assist the stimulation of thinking that promotes competence and expertise. Building on the cognitive systems theory and leveraging the psychological basis for using visual representations, will we be able to discover how to present information that supports interaction for learning?

Assessment in higher education requires that students master essay writing skills and their responses are increasingly benchmarked against standards of competency. Enabling them to receive timely advice about their draft attempts at essay writing can provide insights into the generic skills of essay writing. This type of feedback also opens to the possibility of not only self-reflection but also engaging in a productive discourse with peers and/or a tutor. However, finding a set of knowledge representations that will promote this type of skill acquisition, merits further investigation. It will be matching the types of student activities to these representations that will be essential to aligning assessment with long-term learning. [21].

8. ACKNOWLEDGMENTS

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