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Supporting Computing and Technology distance learning students with developing argumentation skills

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***Abstract*—The development of students' critical thinking skills is an important part of a university education. This paper focuses on helping Computing and Technology (C&T) students improve their argument analysis and construction skills. At the heart of the current approach sits the use of a diagram-based technique for scaffolding argument analysis and construction. The technique, known as argument mapping, has been pioneered in Philosophy degrees. We discuss the specific challenges posed by using this technique in the context of distance learning for C&T students of a large (>1000 students) entry-level gateway module. Our approach includes innovative interactive computer-based formative assessment of argument mapping. After describing the approach, we evaluate it in terms of data from formative and summative assessment, detailed analysis of student work, and feedback from both students and module tutors.**

Keywords— Education, Continuing education, Computer science education, Educational technology

I. Introduction

A widely accepted aim of higher education is the development of students' critical thinking skills, including the skill to analyse and construct arguments. Supporting the development of this skill for Computing and Technology (C&T) students presents specific problems; our experience is that a significant proportion of C&T students view such skills as at best an add-on and at worst a distraction from core C&T skills. In this paper, we describe how we dealt with the integration of argumentation skills in TU100 ('My digital life') [1], a large (>1000 students per biannual presentation) entry-level gateway module for C&T distance learning students at the Open University, which had its first presentation in 2011. TU100 was developed by a large team at the Open University, with the author of the current paper leading the work on argumentation skills-related module materials and assessment. After describing and motivating our approach, the paper presents results and recommendations based on quantitative and qualitative data from the first two presentations of the module.

Approaches to teaching argumentation have been pioneered in Philosophy curricula and tailored to the subject matter of a Philosophy degree [2]. In contrast, students who take a Computing or Technology degree are often directed to generic online "study skills" resources, books (e.g. [3,4]), or a University-wide critical thinking module. This approach has two downsides: firstly, the content, especially of examples, is often not directly relevant to the C&T students and, secondly, the presentation is disconnected from the way C&T are encouraged to think as part of their studies, e.g., broader Engineering and Computational Thinking skills [5].

We addressed the content problem by integrating the learning of argumentation skills tightly with the module content - specifically, a block on the social and ethical impact of computing and information technologies. For example, whilst students work through case studies of how the flow of information on the internet is influenced by individuals, technologies, organizations and the state, they analyze arguments from a variety of sources on why information flow should or should not be controlled (ranging from Google, Amazon and Twitter blogs to Supreme Court judgments). [6] flags this approach of 'mixing' critical thinking with subject specificity as requiring further research.

The method problem is addressed by taking a technique, argument diagramming or mapping (e.g., [2,7,8,10,11,12,13]), developed by philosophers, and adapting it to the C&T audience. Roughly speaking, an argument map is a tree structure; nodes represent claims and edges stand for support or oppose relations between claims. Our students encounter this idea in terms of concepts that chime best with their background: argument maps are introduced as data structures and a step-by-step procedure/algorithm is given for constructing an argument from a text. This way, the activity of analysing an argument resonates with C&T students computing and engineering inspired thinking skills.

In the remainder of this paper, we proceed as follows. Firstly, in Section II we briefly describe the history of argument diagramming followed by empirical and theoretical

This research was carried out as part of the Argumentation Education (ArguEd) project. ArguEd (2011-2013) is funded through the eSTEeM programme at The Open University.

justifications for its use in teaching argument analysis and construction skills. Section III presents background information on the module in which we deployed the current approach. Section IV focuses on our use of argument diagramming in both formative and summative assessment. In particular, we discuss a novel interactive online formative assessment method for argument diagramming. Section V describes our evaluation of the approach in terms data from formative and summative assessment, detailed analysis of student work, and feedback from both students and module tutors. The evaluation results are discussed in the context of a number of research questions in Section VI. This paper ends with a conclusions section, which includes a discussion of lessons learned.

II. ARGUMENT DIAGRAMMING - BACKGROUND

According to [8], the use of diagrams to capture the structure and content of arguments goes back at least as far as the work of the US legal scholar John Henry Wigmore (1863-1942). Wigmore designed charts specifically for representing the legal evidence that is put forward in a trial. In Philosophy, the use diagrams for representing arguments was popularized by the work of the British philosopher Stephen Toulmin (1922-2009) [9]. Whereas Wigmore deployed diagrams for the practical purpose of keeping track of the arguments in a trial, Toulmin concentrated on the theoretical analysis of the underlying 'pattern of an argument'. One of the pioneers of the use of diagrams in education has been Michael Scriven. His seminal textbook [10] uses diagrams that visualize the structure of arguments specifically for teaching argumentation and reasoning. Another milestone is [14], which extends the technique to suppositional reasoning.

Recently, there have been several studies - in the context of teaching Philosophy and general critical thinking skills - that examine whether argument mapping can help students improve their critical thinking skills. For example, both [11] and [7], found that students using argument mapping achieved a substantial gain (0.80 and 0.72 standard deviations, respectively) on pre- versus post-test scores on the California Critical Thinking Skills Test (CCTST). [11] involved students enrolled on an introductory university course to reasoning. [7] included both first year and third year Philosophy students. [11] and the study in [7] with third year students involved teaching argument mapping with Reason!Able, a commercial software package for constructing and evaluating argument maps [12].

Both of the aforementioned studies did not involve control conditions. In [2], the teaching of argument diagramming is compared with a control condition in which more traditional methods for analyzing arguments were used. [2] found a significant effect of the use of argument diagrams on undergraduate philosophy students' performance on the exams that test argument analysis skills (spotting premises and the conclusion, explain and evaluate the connection between premises and conclusion).

In [13], Harrell sets out the theoretical support for using of argument mapping. For this purpose, she refers to Schema theory [15,16,17,18,19]. According to Schema theory, human data processing depends on the use of schemata, representations which contain information about how the data we perceive and process are linked together. For instance, schemata are activated when we read a story to make sense of connections between the individual story steps (temporal succession, cause and effect, etc.). Whereas the skill of reading a text for its plot or story is acquired by young children [19], the schemata for argumentation seem to be less well-ingrained during language learning (e.g. [20,21]).

Argument maps are a means to familiarize students with schemas that they can then use to understand and analyze argumentative text. Additionally, [13] suggests that learning of new schemata can be facilitated by means of visual representations, following the insight that cognitive load during learning [18] can be reduced through the use of graphical representations [22]. In fact, most of the literature on argument maps in teaching does not distinguish between the underlying structure of an argument map and its visual representation. Our approach, as described in the next section, is different in that we do explicitly make the distinction between an argument in terms of its underlying structure, and the visualization of a map.

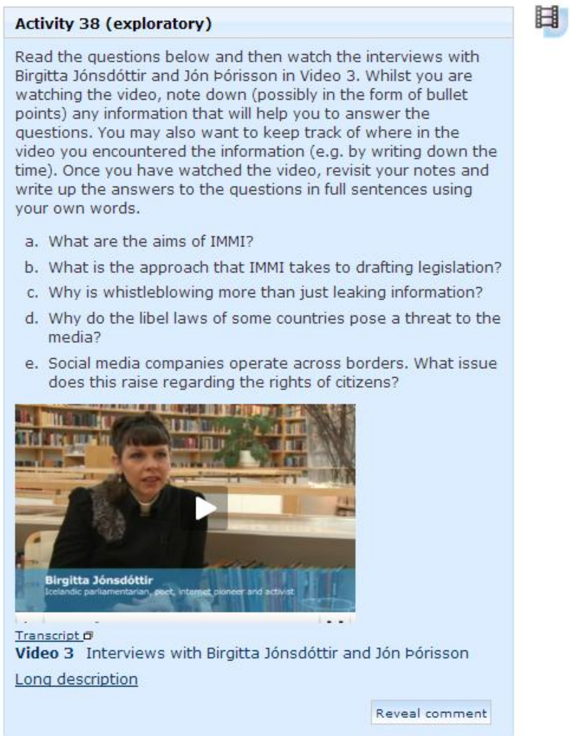

Figure 1. An activity around the Icelandic Modern Media Initiative (IMMI)

III. MODULE DESCRIPTION

The work described in this paper was carried out in the context of TU100 ('My digital life') [1], a large distance learning module (>1000 students per biannual presentation) for Computing and Technology students at the Open University.

The module covers a wide range of topics, including mobile and wireless computing, HCI, programming (in Sense, a language extending MIT's Scratch; the language is used to write programs which control a board, provided with the course, that is equipped with several sensors and actuators, see [24]), and the social and ethical impact of computing and information technologies.

In TU100, argument mapping is tightly integrated with the last topic through a range of examples and case studies. Our students study arguments for and against the free flow of information on the internet (e.g., based on interviews with leading internet activists such as the members of the Icelandic Modern Media Initiative, see Figure 1), and construct their own arguments regarding controversial uses of modern technology (e.g., based on a BBC Radio 4 feature on a dating service for people who are married).

Argument maps are introduced as structures that consist of the following elements:

- a main claim,
- further individual claims or collections of claims that either support or oppose the main claim
- optionally, further claims or collections of claims that support or oppose the aforementioned claims

We emphasize that argument maps can be viewed as abstract structures, regardless of their visualization. In this respect, we aim to use an approach which presents the material in terms that are familiar to and of interest to computing and technology students, i.e., as data structures. We point out that, as with any data structure, argument maps can be visualized with the help of diagrams. A generic example of such a diagram is given in Figure 2.

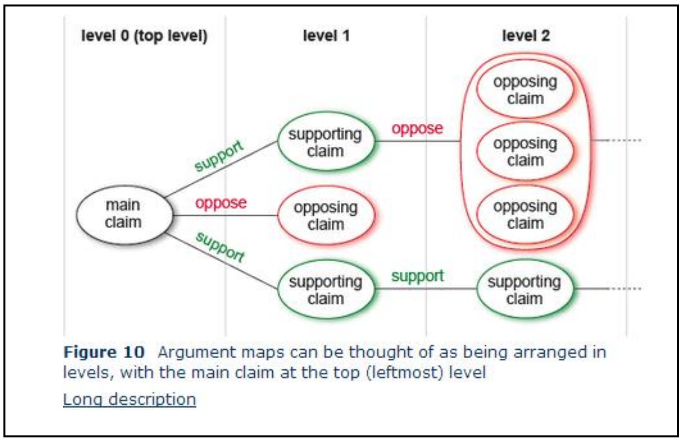

Figure 2. A figure from the TU100 module materials showing the structure of an argument map

Drawing and revising argument maps, along the lines of Figure 2, can be cumbersome. For this reason, we recommend to our students the use of FreeMind (a free open source Java-based tool [25]) to create and revise their argument maps. FreeMind was conceived originally as a mind mapping tool. In contrast with argument mapping, in mind mapping nodes are occupied by topics and/or images rather than claims and the links between nodes stand for associations or causal relationships rather than moves in an argument (such as 'oppose' and 'support'). Argument mapping differs along similar lines from concept mapping (see [23] for details). There is a straightforward way to use FreeMind for argument mapping, which involves using some nodes as relation labels. The students are introduced to this use of FreeMind in a 5 minute explanatory video (see Figure 3).

There are also dedicated argument mapping tools, each with their own strengths and weaknesses; see the overview in [26]. We nevertheless decided to use FreeMind for the following reason. In TU100, our students already needed to come to terms with a significant number of tools and software (ranging from the Sense programming language to Audacity and Google Apps). This included the use of FreeMind for the purpose of mind mapping. Rather than add a further piece of software, we decided that it would be more effective to get our students to use a piece of software they were already using for a different purpose.

For visually impaired students, all argument maps were also provided in a textual format that can be read out using screen reader technology.

Students were asked to submit their course work by saving their maps in FreeMind as .png files. Alternatively, they were also allowed to submit their maps in the alternative textual format.

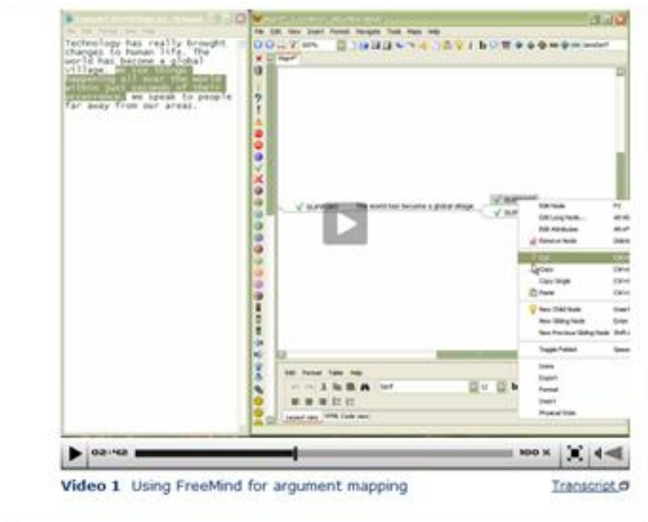

Figure 3. A video from the TU100 course materials which explains how to create an argument map using FreeMind. On the lefthand side, a short argumentative text is shown in notepad. On the righthand side, an argument map for this text is constructed using FreeMind. A voice over explains the steps that are involved.

A further term from computer science that was deliberately used in this course to teach argument mapping, was that of an algorithm. We provided students with a detailed algorithmic description for how to extract an argument map from a piece of text. In a nutshell, this involved first reading the text for the main claim (level 0 in Figure 2) and then iterating through successive levels of opposing and supporting claims until all claims in the text have been accounted for.

This top-down algorithmic approach was inspired by the author's own experience with argument mapping and confirmed by observations of several experienced academics (one expert in argument mapping, one logician and several others with experience in natural language processing), who were set the task of constructing an argument map for a short text whilst following a think-aloud protocol.

The module materials were specifically designed to appeal to Computing and Technology students by using terminology relevant to them. Additionally, the materials explained that being able to construct a coherent argument is a transferable skill that is highly valued by employers. Finally, we explained how work in Artificial Intelligence, an area of Computer Science, is using structures such as argument maps to reason with the information locked up in text for a range of applications, from text understanding to automatic summarization.

The module materials were delivered online through the Open University's Moodle-based Virtual Learning Environment. Students also received tuition from a tutor. Students are organized in groups of 10-20 students that have their own tutor – these are referred to as tutor groups. Tutor groups attended face-to-face (or online) tutorials. At the Open University, tutorials are used primarily for group work and activities (as opposed to traditional lectures). Some, but not all tutors, included in their tutorials their own argument mapping activities.

IV. Assessment

The students' argument analysis and construction skills were assessed both through formative and summative assessment. The formative assessment was delivered as an interactive Computer Marked Assignment (iCMA) on the Open University's Moodle-based Virtual Learning Environment. This assessment did not contribute to the students' final grade, though they did need to meet an overall threshold. Summative assessment consisted of course work which was marked by the student's tutor.

A. *Formative Assessment*

The formative assessment was primarily intended as a way for students to rehearse for the summative assessment. Using iCMAs meant that they got instant feedback. In this section we describe the new type of iCMA question that was developed to scaffold students' argument mapping skills. This was implemented in OpenMark [27, 28], an open source question engine which integrates with Moodle, but allows more flexibility than standard Moodle quizzes.

An example of an argument mapping question is shown in Figure 4. The student is presented with a text that is relevant to the topic they are studying. In this case, they were studying the flow of information on the internet and how it might be controlled by various parties. The text in question is a communication in 2010 from Amazon on why they stopped hosting WikiLeaks data. An argument map template, with gaps, is provided. This template shows the underlying structure of Amazon's argument, but does not specify the position of specific claims. Students are asked to complete the template by placing claims from the text into the template. The claims are labeled A-F and these labels can be dragged and dropped into the argument map template.

When they submit their answer (there is a button for this, which is not shown in Figure 4), they get immediate feedback on which claims have been placed in the right positions. The correctly placed items remain in position, whereas the other items are put back in their original place, see Figure 5. The students have two further attempts. After the final attempt, the correct answer is shown.

Note that for this particular question, with 6 items, there are 6! = 720 possible responses. Because the ordering of the three leaf nodes of the top branch does not matter, there are 3! = 6 correct answers. Thus, the chance of guessing a correct answer on the first attempt is less than 1%.

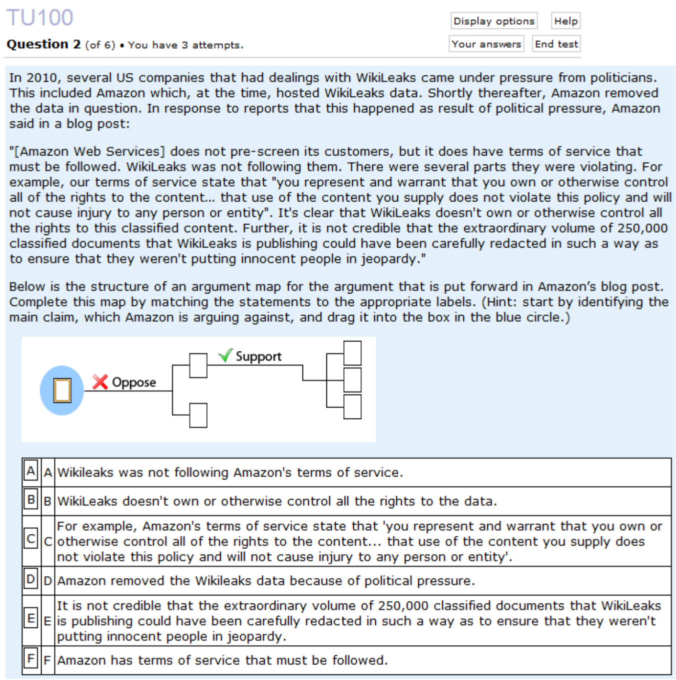

Figure 4. An interactive Computer Marked Assessment (iCMA) question on argument mapping as rendered on the OU's Moodle-based Virtual Learning Environment.

We considered not retaining the correctly placed items in position after each attempt. This would mean that students get no feedback on what they got right until after the final attempt. Given that at each stage, with n items still not in position, there are $n!$ possible responses, we felt that this would not serve the formative purpose of this question. In particular, it might be demotivating for the students. Unlike traditional multiple choice questions, there was also no serious concern about students simply guessing and getting it right.

Each question had five variants. If a student was not satisfied with their score on the variant of a question, they could start again. This resulted in them being presented with one of the variants they had not done yet. In principle, students could continue until they had seen all five variants; they would then be served again with the first variant. Note that when we report iCMA scores below for students on a question, this concerns the score for the variant of the question on which they scored highest.

The standard Moodle quiz engine includes a graphical drag and drop style. It does, however, not cater for the flexibility we require here; in particular, as described above, more than one answer can be correct (given that the ordering of some of the nodes does not matter). To overcome this limitation we used the OpenMark system. This system is also open source and there is a protocol for integration with Moodle. Thus our argument mapping questions were seamlessly integrated with other questions that used the standard Moodle question engine, both in terms of student experience and back-end learning analytics that are gathered from student answers.

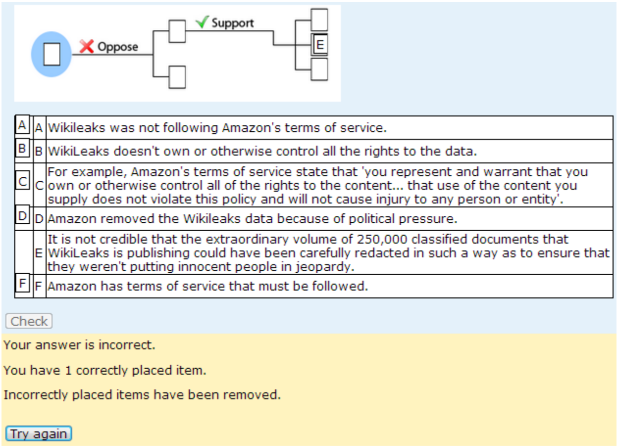

Figure 5. Feedback after one attempt of answering the argument mapping question from Figure 4. The only correctly placed item is E. Not that this figure only shows the bottom half of the page that the students see.

B. Summative Assessment

The summative assessment, which was spread over 6 pieces of course work and one end of module assignment, included a question on argument analysis and construction in the sixth assignment. This question was worth 30 points (out of 100 marks for the full assignment). Students were presented with an article (e.g., on digital rights and the Swedish music industry), a posting in response to the article, and part of an argument map. The question consisted of four subquestions:

(a) Students had to link a claim made in the article with one in the map and classify it as either a proposal (an attempt to persuade someone to do something) or proposition (an attempt to persuade someone to think something).

(b) They had to identify a further claim in the article and insert it into the argument map at the correct position. Note that in contrast with the iCMA question, here there was only an incomplete map, not a template, so they would also need to determine whether the claim is either supporting or opposing another claim.

(c) They needed to identify two claims in the posting and add those also to the argument map.

(d) They were asked to write a summary based on the completed argument map complying with a number of criteria in the module materials on the presentation of arguments. For example, they were instructed to use appropriate connecting phrases (such as"Firstly", "Secondly", "However", etc.) to communicate the argument.

V. Evaluation Results

Our overall aim has been to explore a mixed approach (in the sense of [6]) to teaching argumentation to distance learning Computer Science and Technology students. Two key characteristics of our approach are (a) the integration of a technique called argument mapping with teaching subject matter teaching, and (b) the use of a novel formative interactive Computer Marked Assignment (iCMA) to prepare students for their summative assessment on argumentation. Our primary aim of the evaluation of the approach has been to learn lessons for future practice. This is underpinned by the following research questions:

- Does the argument mapping iCMA question prepare students for the summative assessment on argumentation?
- How do students perceive the mixed approach to teaching argumentation?
- What has been the experience of tutors teaching this course with the argument mapping component?
- How can we help students further improve their argumentation skills?

In order to answer these questions we examined data from the following sources:

- Data on student scores on the iCMA and course work argument analysis and construction question.
- Student answers to the argument mapping course work question.
- Student perceptions on the online student forum of argument mapping and the relevant course work question.
- Tutor perceptions on the online tutor forum of argument mapping and the relevant course work question.

In the remainder of this section, we present the evaluation results from each of these data sources. In the subsequent discussion (Section VI), we relate these back to the research questions.

A. iCMA and course work question scores

Firstly, let us report on the correlation between the performance of students on the iCMA and the course work. In

Figure 6, for the argument mapping questions, the course work question scores (y-axis) are plotted against the iCMA scores (x-axis) in the box-and-whisker plot. Pearson's correlation (excluding the category "did not do iCMA question") r is 0.282 with N=1040 and $p < 0.01$ (two-tailed).

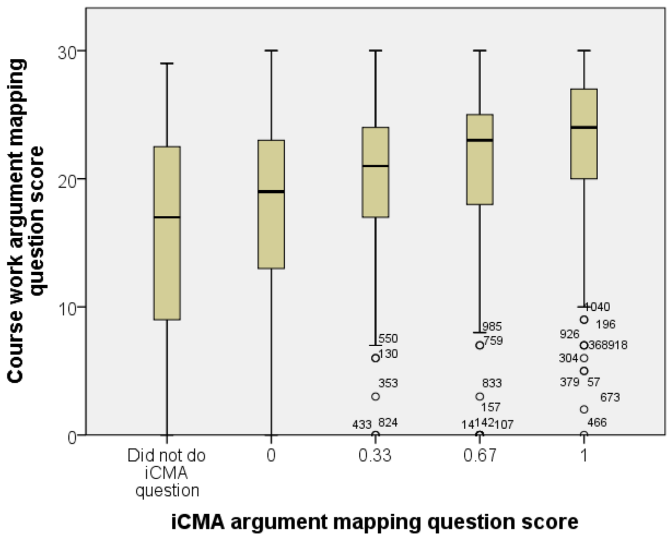

Figure 6. Course work score plotted against iCMA question score - both scores pertain to the argument mapping question.

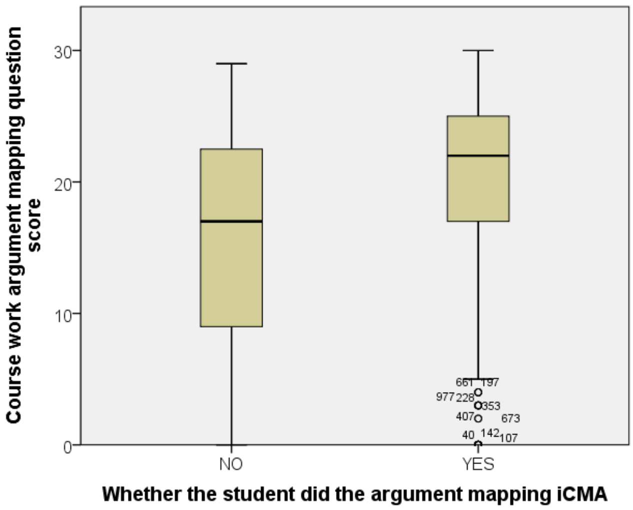

Figure 7. Course work score plotted against whether a student did the iCMA question - both pertain to the argument mapping question.

Figure 7 shows the difference between students that did and those that did not take the iCMA question in terms of their subsequent performance on the course work question. The mean course work question score for students that did not do the iCMA was 15.38 (N=91, SD = 9.081), whereas for students that did do the iCMA the mean was 20.58 (N=1040, SD = 6.729). The difference was highly significant at p<0.0001 (2-tailed t-test, equal variances not assumed, df=98.837, t=5.330).

With the iCMA questions (19 in total, including the iCMA argument mapping question) as fixed factors (iCMA question taken or not) and the score on the course work questions (4 scores in total including the course work argument mapping question) as dependent variables, we found a highly statistically significant overall effect (p<0.001, F=483.603, df=4). In terms of individual iCMA questions, apart from the iCMA argument mapping question (p<0.001, F=15.312, df=1), only one other iCMA question has a statistically significant effect on the argument mapping course work question (with p<0.023, F=5.185, df=1). The latter iCMA question asked students to choose from four options ('a cantenna', 'a PC', …) 'Which of the following technologies may be considered an appropriate technology that will benefit people with limited resources in a developing nation?'

Interestingly, the argument mapping iCMA question also had a significant effect on the two other course work question scores and the course work overall skills score (at p=0.007, p=0.002 and p<0.001, respectively). Out of the 19 factors (i.e., the individual iCMA question scores), only 4 had individually a statistically significant effect on one or more of the independent variables (i.e., course work scores).

B. *Analysis of student answers on course work question*

We divided the course work answers by score (out of 30) into four equal groups using quartiles:

- Quartile 1 (25%, score = 17)
- Quartile 2 (50%, score = 22)
- Quartile 3 (75%, score = 25)

We took a random sample of four scripts from each group and applied qualitative content analysis to these. We arrived at the following classification of student mistakes (resulting in a loss of marks), organized by the groups in which they occurred most:

- Up to Quartile 2:
  - Misreading of the source text leading to incorrect claims (e.g., the article stated that songwriters do not make revenue from sales of concert tickets etc., whereas the student's claim stated the opposite).
  - The argument map is ill-formed (e.g., both support and oppose relations are used simultaneously to link two claims).

- Students simply omitted part of the answer. These were mostly students that also skipped the iCMA argument mapping question.

- Up to Quartile 3:
  - A valid claim has been identified, but it has been placed in the wrong position on the argument map as a result of confusing the argumentative *oppose* relation with a *contrast* discourse relation (in the sense of Rhetorical Structure Theory [25]). For example, ‘Unison also claim it is against their human rights and have the right to make a living like any other profession’ is linked with an oppose relation to ‘Legalising illegal downloading for private use will increase freedom on the internet’. Though there is a contrast between the two (rights of one group versus those of another), the former does not refute or contradict the latter.

- The group above Quartile 3:
  - Correct claims and relations, but some claims needed to be grouped (since they did not independently provide support for another claim). The distinction between grouped and independent claims is introduced in the course materials.

In terms of the answers to the summary question part (d), at the lower end, students omitted the summary or it was presented as a description of the argument map; e.g. ‘The main claim is stated at the first node of my argument map. (…)’. In contrast, high scoring students produced excellent summaries, making use of appropriate connecting phrases (e.g. ‘Legalising illegal downloading for private use will increase freedom on the internet. However, this claim is refuted by the opposing argument that legalising downloading for private use is unlikely to increase freedom, as music is already very cheap and therefore very accessible to the majority of people’).

C. *Student perceptions of argument mapping*

TU100 has an online forum in which students can discuss course related topics. A small number of students (*N*=9) specifically discussed argument mapping and the associated course work. We again applied qualitative content analysis to discover themes in these discussions. The tone was positive about the relevant course materials, e.g.: ‘Block 5 part 5 is very useful. I like writing up arguments and have got some jolly good tips from this section.’. However, one student did raise the question ‘What does it have to do with IT?’. Three other students responded with constructive answers:

- ‘I found that reading it slowly in a quiet corner helped me to absorb it. I agree that is has little to do with technology itself but I do find that it will come in useful in other respects that can affect technology, like articles outlining the ethics of {XYZ}. Being able to dissect technology articles can be useful.

  For example, what are the ethical and privacy implications of having a system in your house monitoring your every heartbeat, every millitre of urine you pass, every stool you pass, and everything you eat and drink? You want to be able to disseminate the overall pros and cons of such a system as well as for each situation. Argument maps are one way of doing this.’

- ‘I agree, they just want to develop us logical arguments thinking, , no idea if what I answered for question 1 is correct or not, today another day of TMA...it looks like it takes more than i thought, good idea that I started earlier....’

- ‘I think argument maps are used quite heavily in AI, but I imagine it's more to prepare us to be able to structure essays in level two subjects better.’

The second student mentions insecurity about whether they answered the argument mapping question correctly. This theme reoccurs in other students’ postings: ‘Q1 also made me a bit paranoid but (…) I realised that I did get the angle wrong and changed it a little.’

Finally, there seemed to be some students which either preferred the argument analysis or the more obviously computing related questions: ‘question 1 bearable, question 2 headache ! huge numbers ! question 3 oh god why am i doing this :-(lol one has to have a sense of humour about it ! :-)’ versus ‘Ok done :). As I said , question 1 was Tough, question 2, and 3 because was computing related for me personally wasn't to tricky.’ The subjective impression regarding difficulty relative difficulty corresponded with the actual score achieved by each of these students: with the former student doing better on the argument mapping question and the latter on the programming/numerical questions. However, when comparing *between* students, the second student did better on each of the three questions than the first student.

D. *Tutor perceptions of argument mapping*

Tutors on TU100 have an online forum in which they can discuss, among other things, their marking of the student work and any difficulties or issues with this. 13 tutors engaged in a discussion about the argument mapping course work question. From this a theme emerged suggesting two different approaches to marking the question. The first approach is characterized by the following comment:

> ‘My students, that I have marked so far, have come up with all sorts of views on the main claim for this question. Nobody has given the official answer’.

In contrast, another tutor personified the other approach:

> ‘I've been tempted on more than one occasion to write that “this technique is widely used in Arts and Humanities where there is no such thing as a right or wrong answer, only well-argued and poorly-argued points”’

There was also a suggestion that argument mapping should have been introduced earlier on in the module:

> I think argument maps can be really useful as a way of structuring / developing ideas and I would have liked to see them introduced much earlier on the module. I think they could havbe been applied to lots of the TMA questions eg the one about home networks, the discussion about synchronous/asynch discussions, etc etc. They seem (to me) more tangible than mind maps, and I might informally introduce some elements of them early in the module next year.

One tutor described how to link the argument analysis question with the programming in Sense question, drawing out similarities:

> In the Skills marking, I've described this as a logical analysis exercise and linked it to the analysis part of the Sense [programming] exercise. Both involve identifying the key elements from material which provides what's needed but not in the order it's needed ("all the right notes, just not necessarily in the right order" - Eric Morecambe). Both involve discarding what Pooh Bah called "merely corroborative detail, intended to add a touch of artistic verisimilitude to an otherwise bald and unconvincing narrative" (W S Gilbert, Mikado). Both involve organising the material into a logical structure for further processing.

VI. Discussion

In this section, we discuss the results that we reported in the previous section. We use the four research questions that we identified to structure this discussion.

A. *Does the argument mapping iCMA question prepare students for the summative assessment on argumentation?*

Our results show a clear relation between whether students did the argument mapping iCMA question and their performance on the argument analysis course work question (Fig. 7). Additionally, we found that only one of the other iCMA questions also had a (weak) statistically significant effect on student performance on the argument analysis course work question. However, we also found that taking the argument mapping iCMA question had an effect on student performance on all of the other course work questions.

For practical and ethical reasons, our data were obtained in an observational rather than an experimental study. Consequently, they do not license us to infer any causal relations. In particular, we *cannot* conclude from the current results that students did well on the argument analysis course work question *because* they did the argument analysis iCMA. In particular, we need to keep in mind that students self-selected whether to do the argument mapping iCMA question. It is very well possible that this choice separated the students into motivated and less motivated students, explaining subsequent differences in performance between the two groups. This interpretation of the results is also supported by the finding that whether students took the argument mapping iCMA had an effect on performance on *all* three course work questions and also on the mark they received for general skills (exhibited throughout answering the three questions).

Interestingly, out of all the 19 iCMA questions, only the choice to do the argument analysis question had a positive effect on student performance on all of the course work components. Under the interpretation that this choice separates students according to their degree of motivation, this suggests that the argument analysis iCMA question (in contrast with the other iCMA questions) is particularly effective in distinguishing between motivated and less motivated students.

Note that for those students that did do the argument mapping iCMA question, how well they did on the iCMA question is only weakly correlated with their performance on the argument analysis course work question (r = 0.282, Fig. 6).

B. *How do students perceive the mixed approach to teaching argumentation?*

Interpretation of the data on student perceptions requires caution because only a very small proportion of the entire student population taking TU100 engaged in the specific forum discussions we reported on.

In the forum discussion we observed that one student questioned the rationale for including argument mapping in the course. This would suggest that for this student the mixed approach did not have sufficient appeal. This student is however counterbalanced by three other students who responded to the student's posting pointing out why argument mapping is relevant. We also observed that more generally the block on argument mapping was perceived positively by the forum participants.

The forum discussion on the argument mapping assessment highlights some students being insecure about whether they answered the argument mapping question correctly. This may be a result of the more open-ended nature of this question, in comparison with for example the programming question (where there is more direct feedback to the student in terms of whether their program works).

C. *What has been the experience of tutors teaching this course with the argument mapping component?*

Some tutors also struggled with the open-ended nature of the argument mapping question – one tutor raised the issue that only few students returned the 'official answer'. Other tutors pointed out that for this type of question there is no unique/single correct answer. This was something that was also highlighted in the marking guidelines to the tutors: "More generally, please exercise your judgement when evaluating the students' maps. If a map created by a student differs from the maps given here, but is accompanied by a reasonable explanation, award appropriate marks." This seems to be an issue which is particularly relevant to Computing and Technology tutors, where the model behind many other assessment questions is indeed that there is a single correct answer. In this respect, argument mapping presents a challenge.

One of the tutors provided insightful comments which linked the argument mapping skills to programming skills in terms of underlying shared skills of 1) abstraction (i.e., identifying key element in material and discarding superfluous details and 2) fitting material into a logical structure for further processing.

D. How can we help students further improve their argumentation skills?

To address this question, we examined the student answers to the course work argument mapping question in more detail. One particular finding that stood out was that students often did not distinguish between genuine argumentative relations (opposing or supporting a claim) and other relations that might hold between claims (e.g., contrast). For instance, the claim "John eats a lot each day" is supported by the claim that "John's food intake exceeds 5000 calories on a daily basis." The claim that "Mary does not eat much each day" bears the contrast relation to the first claim about John. Some students would, however, classify this as opposing the original claim, even though it does not contradict or refute that claim.

This raises the question whether teaching of argumentation should go beyond teaching students argumentative relations and explicitly compare these with other discourse relations in the sense of [29].

VII. CONCLUSION

In this paper, we described a mixed approach to teaching argumentation to distance learning Computing and Technology students. In particular, this included:

- Integrating the teaching of argumentation skills with subject matter content (a block on the ethical and social implications of computing technologies).
- The use of the argument mapping technique, but adapted to the context of Computing and Technology students by presenting it in terms that resonate with this student population (data structures and algorithms).
- The separation of argument maps as structures from their visualization. This included the use of an alternative textual presentation form of argument maps for visually impaired students.
- The introduction of a novel formative interactive Computer Marked Assignment (integrated with Moodle) to scaffold students' argument mapping skills, in preparation for summative course work on argument analysis and construction. This approach is particularly helpful in providing distance learning with instant feedback on their argument analysis skills.

We evaluated the current approach using data from student assignments (marks and detailed analysis of student work), online student and tutor forums. Here we would like to highlight two of the insights this afforded us:

- First, a specific point about teaching argumentation. Argumentation is one form of discourse among many. From examining student mistakes in their assignments, we found that they might benefit from explicitly teaching about the differences between argumentative and other discourse relations (i.e., 'oppose' and 'support' versus 'contrast', 'narrative sequence', etc).
- Secondly, a more general point. The mixed approach to argumentation skills teaching for Computing and Technology students requires a change of perspective from both some students and tutors. One could characterize this as a culture change: for argumentation assessment questions, one needs to let go of the idea that there is a single correct "official" answer and move to focusing on whether there is a well-argued or poorly-argued point.

We hope that this paper provides both practitioners and researcher with insights and ideas for integrating critical thinking skills into STEM subjects teaching and for further investigating how to do this most effectively.

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