Chen, W. et al. (Eds.) (2016). Proceedings of the 24th International Conference on Computers in Education. India: Asia-Pacific Society for Computers in Education

“VC/DC” - Video versus Domain Concepts in Comments to Learner-generated Science Videos

H. Ulrich HOPPE[a*], Maximilian MÜLLER[b], Aris ALISSANDRAKIS[b], Marcelo MILRAD[b], Christina SCHNEEGASS[a] & Nils MALZAHN[a]
[a]*Rhine-Ruhr Institute for Applied System Innovation (RIAS), Germany*
[b]*Linnaeus University, Sweden*
*hoppe@collide.info

Abstract: The recently finished EU project JuxtaLearn aimed at supporting students’ learning of STEM subjects through the creation, exchange and discussion of learner-made videos. The approach is based on an eight-stage activity cycle in the beginning of which teachers identify specific “stumbling blocks” for a given theme (or “tricky topic”). In JuxtaLearn, video comments were analyzed to extract information on the learners’ acquisition and understanding of domain concepts, especially to detect problems and misconceptions. These analyses were based on mapping texts to networks of concepts (“network-text analysis”) as a basis for further processing. In this article we use data collected from recent field trials to shed light on what is actually discussed when students share their own videos in science domains. Would the aspect of video-making dominate over activities related to a deepening of domain understanding? Our findings indicate that there are different ways of balancing both aspects and interventions will be needed to bring forth the desired blend.

Keywords: learning analytics, learner-generated content, video making, network-text analysis

1. Introduction

The recently finished European project JuxtaLearn explored the potential of fostering learning in different fields of science (or STEM) by stimulating curiosity and understanding through creative performance on the part of the students. Concretely, the students’ performance is substantiated in the form of creative video making (including idea generation, authoring of a storyboard, video taking and editing) together with the sharing and commenting of videos in a learning community. The videos are conceived in such a way as to combine or “juxtapose” a dramatized story or narrative with the representation of domain concepts. In their collaboration around videos, learners may take on different roles in their teams such as actors, editors or production directors. Video production is followed by sharing the videos on a learning platform with annotation and discussion facilities.

The JuxtaLearn approach can be seen as a kind of “second order inquiry learning” in that the creative process follows an initial phase in which the learners appropriate the basic concepts of the domain. The approach is neutral with respect to the initial pedagogical framing of the prior knowledge building processes. From an educational design perspective, the JuxtaLearn approach is based on the notion of “threshold concepts” (Meyer & Land, 2003) to characterize knowledge elements that are central and critical for important shifts of understanding. In the JuxtaLearn approach, threshold concepts are represented as so-called “tricky topics” with subordinate “stumbling blocks”. Initially, the selection of tricky topics and stumbling blocks depends on the teachers’ choices. In the system’s knowledge-based backend, these concepts are integrated into an evolving general domain ontology.

The basic JuxtaLearn process (see Figure 3 for an example) comprises eight steps: (1) identification of tricky topics, (2) demonstration of subject matter, (3) interpretation of the subject matter by the students, (4) video enactment, (5) composition of a video, (6) sharing the video with others, (7) discussion of the video, and (8) review of the results.

There is clear practical evidence of the positive motivational effects of video making and sharing in terms of high involvement and engagement that is not limited to only a few students. However, we cannot be sure if this actually leads to better learning in the domain. In the study reported here, we want to shed light on this question by characterizing the focus of student activities especially in the phase of sharing and commenting between video-related and domain-related communications. In our analysis, we particularly rely on advanced network analysis techniques.

2. Background

2.1 Pedagogical ideas and challenges

The JuxtaLearn approach is based on pre-structuring the domain in the form of a micro-curriculum. Here, the definition of the curricular ingredients of specific learning scenarios relies centrally on threshold concepts as defined by Meyer & Land (2003). Practically, the selection of threshold concepts depends on the teachers' choices in the form of tricky topics and subordinate stumbling blocks; it is not derived from a pre-existing domain ontology used as a normative reference. We see the acquisition and appropriation of these concepts by the learners as a process of knowledge revision and conceptual change (cf. Chi, 2008, for a synoptic view of this perspective). The acquisition of threshold concepts does not correspond to normal extensions of the learner's pre-knowledge (called *enrichment* by Chi, 2008) but to knowledge revisions that arise from cognitive conflicts between pre-knowledge and new phenomena or dependencies to be explained (Vosniadou, 2007).

JuxtaLearn's choice of video making and sharing as central activities is based on the assumption that there would be positive motivational effects of video usage (both active video production as well as video sharing/viewing) on STEM learning. This assumption is supported by the success of video-based learning platforms such as Khan Academy (www.khanacademy.org). Video production is considered beneficial for the motivation and learning by several authors (Jonassen, 2000; Zahn et al., 2005). Regarding the underlying learning principles, this approach can also be considered as "reflection-in-action" (Schön, 1987) as the students construct their own videos.

However, there is a potential threat to the intended learning effects in possibility that students concentrate their efforts on producing "nice" videos rather than improving and deepening their understanding of the domain. In the JuxtaLearn practice, this has been counter-balanced by focusing on the threshold concepts (tricky topics) and related stumbling blocks identified and targeted by teachers. Especially in the initial stages of the learning process, emphasis has been placed on the accuracy of the students' representations of the concepts by comparing their interpretations with reference examples provided by the teachers. Also, the task specifications given to the students include collections of stumbling blocks as targets.

2.2 Network-Text Analysis of video comments

In order to intelligently analyze and support the sharing and commenting of videos, we have adapted and used specific techniques for the analysis of learner created textual artifacts to characterize the learners' understanding of science concepts in terms of semantic networks. In an initial phase of the project, the textual artifacts were video comments from existing web-based learning platforms such as Khan Academy[1] or YouTube[2]. These sources provide a vast amount of videos on different STEM topics and offer the option to enter into a learning dialogue with other users (learners). Although these videos are mostly in "lecture style" (voice + screen capture from a whiteboard using hand-written notations) and not "dramatized", the process of sharing and discussing is comparable to the type of "domain talk" that we expect. With this material, content-related learning analytics techniques have been successfully used to identify the students' models of understanding and misconceptions (Daems et al., 2014). These results form a basis for supporting teacher in supervising their students' supervision as well as for the direct scaffolding of learners.

[1] https://www.khanacademy.org
[2] https://www.youtube.com

Our basic idea and approach was to generate network representations from knowledge artefacts originally created by students or experts and to apply structural measures to these representations in order to detect similarities or mismatches. The underlying analysis process used Network-Text Analysis or NTA (Carley et al., 2013). In NTA, the conversion of texts to networks is based on the following processing scheme: A text window runs over a normalized version of the text (i.e. a pre-processed comment, after stopword deletion and stemming) and every co-occurrence of terms in one window is counted as a link between the related concepts. Using an underlying so-called meta-thesaurus, concepts are classified according to distinct categories (such as people, locations, domain concepts, etc.).

In a qualitative analysis of existing data from Khan Academy and YouTube (Daems et al., 2014), we found that certain keywords were often used to phrase questions around the videos. These words (e.g. related to explanation request) may indicate a specific information needs or problems of understanding. We propose that these keywords or key phrases (such as "explain x", or "how to distinguish x and y?") represent "signal concepts" that indicate a specific relationship either between the author and a domain concept or between two domain concepts. Unary signal concepts refer only to one domain concept and typically express a specific information need or problem of understanding in the part of the author. Binary signal concepts reference two domain concepts in combination or inter-relation. Examples of unary signal concept are *help_needed* or *explain*, which may indicate that the author has a problem in understanding the connected domain concept. A typical example for the binary type is *difference_between* related to distinguishing two domain concepts.

2.3 Network clustering techniques

Network analytic techniques are often subsumed under the heading of "Social Network Analysis" or SNA. However, related techniques are not exclusively limited to dealing with actors and social relations as basic elements. So-called "two-mode networks" (Wasserman & Faust, 1994) are based on relations between two distinct types of entities, prototypically named "actors" and "affiliations". Here, the "affiliation" type can be of very different nature, including, e.g., publications as affiliations in relation to authors as actors in the context of co-authoring networks. In general, two-mode networks can be used to model the creation and sharing of knowledge artefacts in knowledge building scenarios. In pure form, these networks are assumed to be bi-partite, i.e. only alternating links actor-artefact (relation *created/modified*) or artefact-actor (relation *created-by/modified-by*) are allowed.

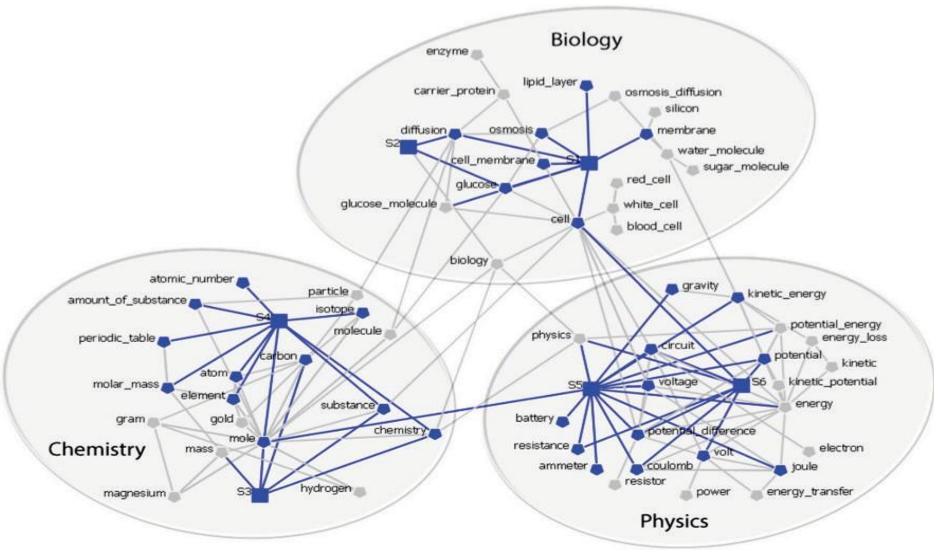

Figure 1. Topic-topic and person-topic relations extracted from transcripts of teacher-student workshops

The results of NTA can be represented as multi-mode networks in the described sense. Figure 1 shows the result of applying NTA to transcripts from teacher-student workshops conducted in the context of JuxtaLearn (Hoppe et al., 2013). The different topics had been initially presented by students in a flipped classroom setting and were then discussed in the whole group. The resulting networks reflect nicely the different topics from the areas of biology, chemistry, and physics as more densely connected sub-networks. Here *topics* (pentagon-shaped nodes) and *topic-topic* relations are depicted in grey, whereas *persons* (square nodes) and *person-topic* relations are colored blue. The number of connections between one actor and surrounding topics (also called "degree") indicates the thematic richness of this actor's contributions. In this sense, the students S4, S5 and S6 score clearly better than S2. In addition, S5 and S6 share many common topics and both have made contributions to different fields (physics/chemistry and physics/biology). This shows that network measures capture interesting characteristics of group interactions and discussions.

This two-mode network (see Figure 1) could be easily "folded" into a pure social network of actors (i.e. students) by inter-linking any pair of actors who share a common topic. This, however, goes along with loss of information and structure (in the ensuing one-mode network, S3, S4 and S5 would form a triangle with a linear tail through S5-S6-S1-S3), and the substructure in terms of network clusters would no longer be explicit. Although network clustering techniques such as modularity clustering (Newman & Girvan, 2004) or clique percolation (Derenyi, Palla & Vicsek, 2005) were originally defined for the one-mode case, recent developments have extrapolated these methods to two-mode networks (Sawardecker et al., 2009; Hecking et al., 2014). This provides us with algorithmic solutions for detecting cohesive substructures in the original two-mode networks. Even in the absence of rich data sources, bipartite connectivity analysis allows for identifying quite fine-structured relational patterns. Such techniques have recently been employed to characterize user roles and emerging themes in a MOOC discussion forum (Hecking, Chounta & Hoppe, 2015).

3. The JuxtaLearn Video-Making Process

The basic idea of the video performance part of the Juxtalearn process is very similar to that of project-based learning (Krajcik et al., 1997):

1. Engage students in investigating an authentic question or real world problem that drives activities and organizes concepts and principles [driving questions]
2. Result in students developing a series of artefacts, or products that address the question/problem.
3. Allow students to engage in investigations
4. Involve students, teachers and members of the society in a community of inquiry as they collaborate about the problem
5. Promote students' learning using cognitive tools

While the students are planning for and working on their specific video performance, the teachers have to help all groups to work productively, i.e. they have coordinate the students where necessary, help the students with their topic related questions and keep them motivated and engaged.

To support the students' learning we provide two palettes: a creative performance palette and a practical performance palette. Students must use the creative performance palette to start crafting their performance and to discuss what they are doing. This approach favours distributed creativity. The practical performance palette supports the students in juxtaposing their creative performance with their teacher's standard teaching activity (STA), e.g. a classroom experiment or a talk about the subject matter, by providing reminders, lists and checkpoints.

A video performance has five steps: development, pre-production, production, post-production and upload and screening. The students' creativity is encouraged by a creative performance palette at the development and post-production steps. At post-production, students may need to draw again on the creative performance palette. Of course, the creative process runs throughout the discussion of their video performance enabling differing perspectives on similar STEM topics offering opportunities for understanding. The creative performance palette is made available either as a pack of cards from which to peruse and choose or as an interactive palette on a tabletop (if available). Each card will identify itself as genre, format or story and have the name of the suggestion, along with a description and at least one example. A storyboard acts as a road map to help students create a shared language and providing a solid foundation on which to place the components of the video. It is a structure for the working out of ideas and the overall visual design of a video.

The learning process takes place in ClipIt (Llinás et al., 2014; see Figure 2), a web-based learning environment specifically tailored to supporting the JuxtaLearn process. It acts as central point of interaction between the users (students and teachers) as well as different system components like e.g. table tops, large screen displays and learning analytics toolkits. The finished videos and the storyboards are to be discussed by the students with their peers to stimulate reflective discussions and improvements. Of course, the learning outcome severely depends on the amount of talk on task particularly on the STEM domain concepts in contrast to video making related discussions about “special effects” or “funny scenes”. Thus, we want to investigate if a student group is dealing with the “right” concepts during a JuxtaLearn learning process iteration.

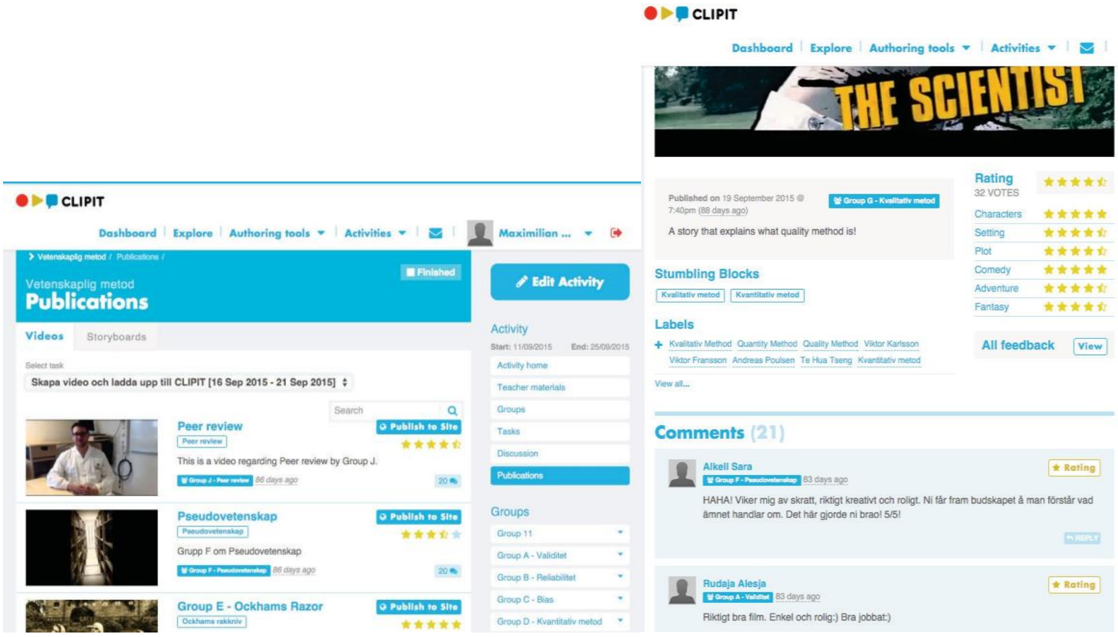

Figure 2. Left: Shared videos (publications) created by students (excerpt) / Right: comment view.

4. Evaluation

The experiment was conducted with 39 first year students as part of the course “Studies in Media Technology” in the Bachelor programme “Interactive Digital Media” at the Department of Media Technology at Linnaeus University.

4.1 Experimental setup

A field trail was conducted over two weeks (September 11-25, 2015). The first week was dedicated to “designing and composing the JuxtaLearn videos”. The second week was focused on sharing of videos among the peers, feedback and discussions (see Figure 3). The students were equipped with iPads, video cameras and storyboard templates (see Malzahn et al., 2016). The students were free to choose which video editing tools to use, but they were given an introduction to the YouTube video editor as part of the introduction session in the beginning of the trial. They were supervised by a lecturer in Media Technology, the course coordinator, two researchers and two research assistants. Every session was directly connected to a specific step of the JuxtaLearn process in order to give it a well-structured frame and scope. The teacher gave a 3-hour lecture on the tricky topic of “scientific methods” to the students. Furthermore, he provided complementary teaching material, which the students could use (and had to review) to prepare for the assignments around the creative video editing activities.

Although this course is essentially of propaedeutic nature, the students were graded to increase their commitment and external motivation. Accordingly, specific mandatory individual and group assignments were given along the steps of the JuxtaLearn process, such as quizzes, storyboards, videos, and feedback tasks comprising of ratings and comments (see Figure 3).

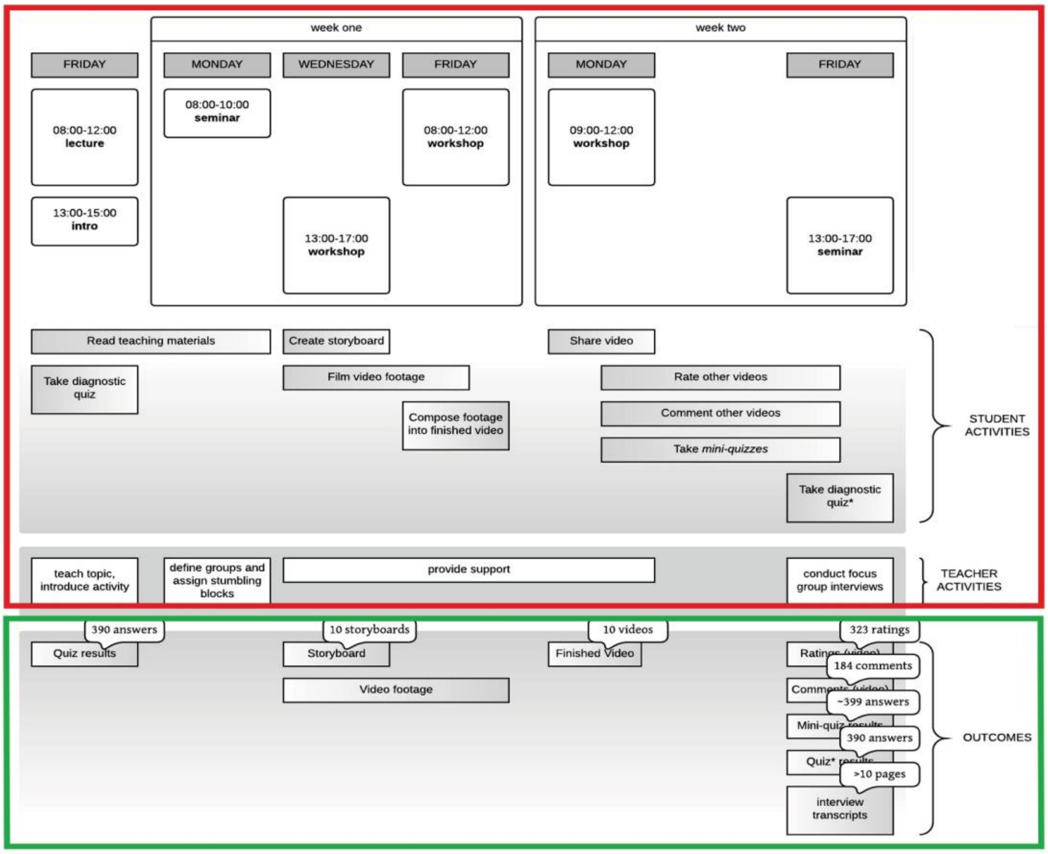

Figure 3. Structure, schedule, activities (red box, top) and outcomes (green box, bottom) of the JuxtaLearn scenario conducted at LNU

Each student group had to work on one of the following Stumbling Blocks identified by the experienced teacher: pseudo-science, peer-review, Occam's razor, validity, reliability, bias, hypothesis, qualitative method, quantitative method, empiricism. At the beginning of the intervention, the students had to take a diagnostic quiz, which was used to identify their knowledge in regard to the stumbling blocks of the tricky topic. Then the groups were formed according to their quiz results by the teacher, targeting heterogeneous groups concerning the overall understanding and specific gaps in regarding of the stumbling blocks. After the video creation steps (taking place in two workshop sessions; see Figure 4) the groups were asked to watch, rate, and comment on the videos of all other groups. Figure 2 shows a snapshot of a video on CLIPIT with comments and ratings during this stage. These activities lasted for four days during the second week of the trial. Afterwards, the students joined a seminar comprising of focus groups (in batches of two groups each) to reflect on their performances and discuss about the overall JuxtaLearn process and their experiences.

4.2 Qualitative observations and results

The results presented in this section are based on focus group sessions with the students after the session, as well an interview with the teacher.

Overall, the students reported a positive experience about working with the storyboards, which allowed them to "more easily structure [their] work", and helped them "to see the bigger picture of [their] video". Students reported that they referred to their storyboards while shooting and editing their videos, as they helped them to stay focused on their initial plan and scenes. The students mentioned they did not have a problem with using the video editing tools. Furthermore, they mentioned they had at least one group member that had prior video editing experience. However, they stated that the time was so limited that they could not go into too much detail with the video editing anyway.

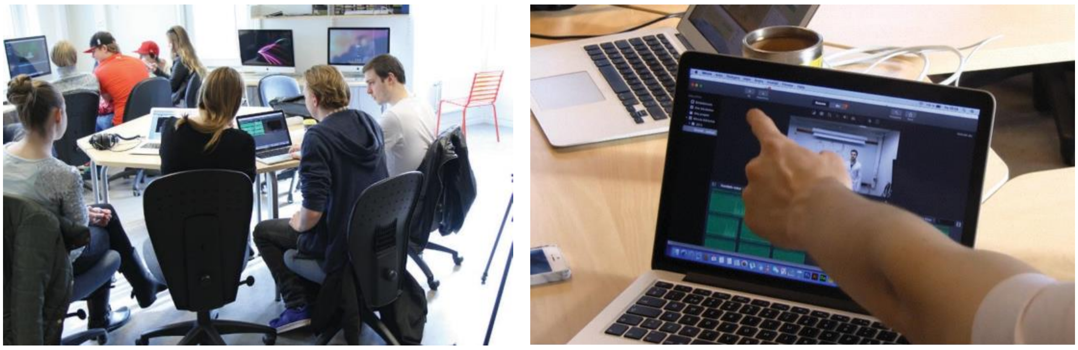

Figure 4. Students working on the videos.

The students perceived that the comments they received were not particularly constructive in the sense of providing explicit directions on how to modify and improve their videos, or very critical about the way they presented their topic. At the same time, most of the students admitted that they avoided being very critical and detailed when providing comments and they were concerned about how their comments would be perceived. Some students suggested introducing anonymous commenting to address these concerns, while others suggested the use of templates or guidelines for what and how to comment. They also mentioned that they had received better comments offline while discussing with other classmates.

The interview with the teacher had three main points of discussion: student efforts (distribution over video and domain related activities), characterisation of the overall learning gain, comparison with earlier instances of the course. According to the teacher, the students seemed to have spent more time with the video making activities, rather than discussing about the domain. Students did learn about the topic assigned to their group, however it is not clear if (and how much) they also learned about the other topics. Previous instances of the course included more individual and "deep" activities, such as peer-review of published bachelor theses and meta-reviews of these peer-reviews; in comparison, this activity was more "simple".

We could observe a distinct approach that the students took during the feedback and discussion phase of the second week of activities. Even though they had four days to engage in the discussions using comments on videos, they saw this task just as another step to complete the assignment and wanted to complete it as soon as possible, i.e. giving a comment and rating to fulfil the task and not really engaging in further discussion. Regarding the students' commenting activities in more detail, the following observations were made:

- In contrast to the majority, one dominant student wrote very extensive and detailed comments, both in relation to the topics but mainly related to technical issues (e.g. "the video would be better if it was filmed as 1080p").
- Another student, pointed out quite strongly in the focus group interview that she did not like that everybody was so "nice" in the comments and that she perceived the comments as a way for her to be critical and receive feedback.
- The comments on videos could not be edited after submission. Students reported that this lowered their engagement with in the commenting tasks, because they wanted to be completely sure before commenting on others' creations. Furthermore, some students expressed that it would have been helpful to give users the option to have anonymous roles, because they were afraid that some people could have taken comments very personally.

4.3 Analysis based on network clustering

For the computational analysis of this learning experience, we have to rely on the video comments as textual artefacts. An analysis in terms of learning or knowledge gains would not be adequate given that original working groups dealt with different themes without really covering a comprehensive set of shared topics. In this view, the question regarding the balance (or imbalance) between different types of concepts (video versus domain) boils down to contrasting "video talk" and "domain talk" when looking at the comments. A first indication can be derived from the sheer number of occurrences of certain terms ("video": 26, "understand": 24, "text": 13, "explain": 12, etc.). Beyond this "surface level" we assume that there is a discourse that materializes in the interlinking of topics (video or domain concepts) appearing in the comments on the one hand side and authors (or commentators) on the other. This is captured by analyzing the cohesive structure of the bipartite topic-author network. Here, more densely connected parts of this network would indicate "islands of discourse".

The first step in this data processing chain is the extraction of concepts (topics) and concept-author relations. This step makes use of NTA using the more recently developed ConText tool (Diesner, 2014). With our data set of 450 comments, this resulted in a network comprising 122 concepts and 30 authors. The concepts were further classified into "video concepts" (vc: 74 items) and "domain concepts" (dc: 48 items). Due to our interest in discourse clusters based on bipartite inter-connectivity, peripheral nodes (students or concepts with only one connection) were filtered out using a so-called *2-core reduction*. The resulting network was clustered using an algorithm based on bipartite modularity optimization (Hecking et al., 2014). This technique works bottom up from smallest units and yields biggest clusters that maximize the inner connectivity of the clusters. It is important to notice that this method leads to a network partition, i.e. each node will appear in exactly one cluster (no nodes left out and no overlaps!).

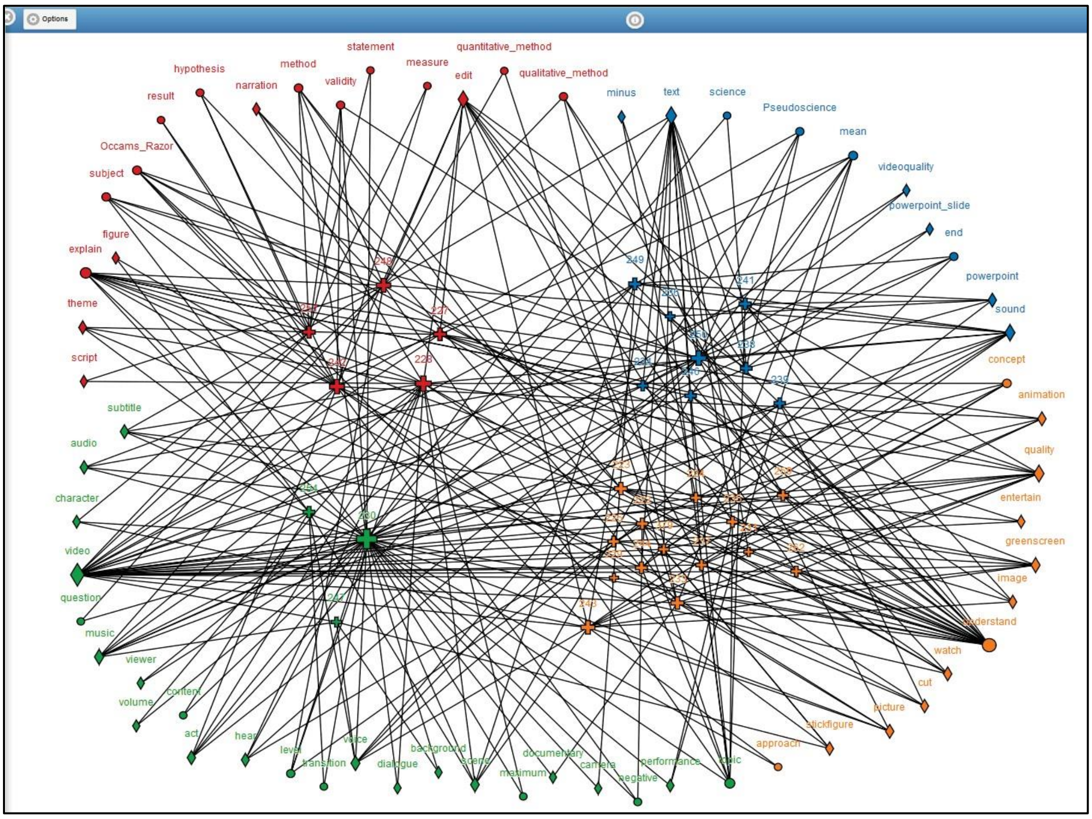

Figure 5. Network clusters resulting from bipartite modularity clustering

Figure 5 gives a visual representation of the clustered network generated by the SISOB workbench (Göhnert et al., 2014). This network comprises all 30 users (depicted as crosses) and contains 61 concepts, among these 36 video concepts (diamonds) and 25 domain concepts (circles). The algorithm resulted in four bipartite clusters (red, blue, orange and green). What is also obvious is the dominant role of one specific user (number 230). The orange cluster has the highest number of users and exhibits a clear dominance of video concepts (but not many concepts overall). The green cluster contains is highly video-centric with many concepts and few users (only three users, including #230). The blue cluster is more balanced between *vc* and *dc*, however with not too many concepts overall, and the red one gathers a big share of the domain concepts around five users.

We should interpret these clusters as "regions of cohesive discourse" (see Table 1 for an overview). In this sense, only the red cluster shows a strong domain orientation combined with an overall high productivity. The green cluster shows the highest productivity, yet is very video-centric and dominated by one user. So, the red and the green cluster are extreme opposites. The large share of not very productive users (22 out of 30) is gathered in the other two clusters (blue and orange), with the blue one being less video-centric than the orange one.

Table 1: Cluster characteristics

	Number of users	Number of video concepts	Number of domain concepts	Productivity ratio (vc + dc) / users
Cluster 1 (red)	5	5	11	3.20
Cluster 2 (blue)	8	6	4	1.25
Cluster 3 (orange)	14	9	3	0.86
Cluster 4 (green)	3	16	7	6.33

5. Discussion & Conclusion

Overall, our analysis of the video commenting behavior shows the overall tendency that “video talk” dominates over “domain talk”. A more detailed view indicates that there are huge individual differences, with a majority of the participants being only minimally compliant with the given assignments in their mainly video-related commenting activity. For the two more productive clusters, we see a quite polarized picture: One cluster involving five students (all with an above-average activity level) elaborated on a quite rich set of domain concepts, whereas the other cluster with three students, among these one very dominant, covered many topics that were mostly video-related.

As for the pedagogical “lessons learned”, we conclude that students should receive stronger stimuli to actively comment and discuss (making more use of replies to comments), and to not only concentrate on the instrumental, surface-level aspect of video quality but rather to engage in “domain talk”. This corresponds to qualitative observations that also indicate the need for more guidance and clearer specification of requirements. Interestingly, the dominance of “media talk” over “domain talk” is not limited to pedagogical scenarios. A similar phenomenon has also been found in a study of the press coverage of video documentaries related to issues of social justice (Diesner & Rezapour, 2016). Here, the press tended to comment on the documentaries rather from a media quality than a content point of view.

Regarding information provided by our analytics approach, we are very satisfied with the detailed insights given by the bipartite cluster analysis. It should be noted that this analysis is partly based on human decisions in the selection and classification of target vocabularies (i.e. the sets of domain and video concepts). In cases of doubt, this was calibrated by looking at the occurrences in the context of the comments. On this basis, e.g. *text* has been categorized as a video concept. Concepts like *explain* or *understand* are quite frequent and have been classified as domain concepts, or more specifically as indicators of “domain talk”. This is consistent with our previous work on “signal concepts” (Daems et al., 2014), and it has been corroborated by recent findings in the analysis of forum postings in MOOCs: Wise, Cui & Vitasek (2016) have identified words of this type as strong indicators for content-related posts (as opposed to socializing or organizational posts).

Although the bipartite network analysis in its current form is a tool for researchers and analysts, we are confident that the essential information can also be conveyed to teachers to improve their reflective practice and teaching quality. If network analyses of the above type had been available to the instructors, this would have given them quite detailed and specific indications for interventions.

Acknowledgements

The research on which these results are based has received funding from the 7th Framework Programme (FP7/2007- 2013) of the European Community under grant agreement n° 317964 JUXTALEARN.

References

Carley, K. M., Columbus, D., & Landwehr, P. (2013). AutoMap User's Guide 2013 (Technical Report No. CMU-ISR-13-105) (pp. 1–219). Pittsburgh: Carnegie Mellon University, Institute for Software Research. Retrieved from: www.casos.cs.cmu.edu/publications/papers/CMU-ISR-13-105.pdf

Chi, M. (2008). Three types of conceptual change: Belief revision, mental model transformation, and categorical shift. In S. Vosniadou (Ed.), *International Handbook of Research on Conceptual Change* (pp. 61–82). New York, Oxon: Routledge.

Daems, O., Erkens, M., Malzahn, N., & Hoppe, H. U. (2014). Using content analysis and domain ontologies to check learners' understanding of science concepts. *Journal of Computers in Education*, *1*(2-3), 113-131.

Derényi, I., Palla, G., & Vicsek, T. (2005). Clique percolation in random networks. *Physical Review Letters*, *94*(16), 160202.

Diesner, J. (2014). ConText: Software for the integrated analysis of text data and network data. Paper presented at the Social and Semantic Networks in Communication Research. Preconference at *Conference of International Communication Association* (ICA), Seattle, WA.

Diesner, J., & Rezapour, R. (2015). Social computing for impact assessment of social change projects. In *Social Computing, Behavioral-Cultural Modeling, and Prediction* (pp. 34-43). Springer International Publishing.

Göhnert, T., Harrer A., Hecking T., & Hoppe H. U. (2014). A workbench for visual design of executable and re-usable network analysis workflows. In Kawash, Jalal, (Ed.): *Online Social Media Analysis and Visualization* (pp. 181-199). Springer International.

Hecking, T., Ziebarth, S., & Hoppe, H. U. (2014, March). Analysis of dynamic resource access patterns in a blended learning course. In *Proceedings of the Fourth International Conference on Learning Analytics and Knowledge* (pp. 173-182). ACM.

Hecking, T., Chounta, I. A., & Hoppe, H. U. (2015). Analysis of user roles and the emergence of themes in discussion forums. In Proceedings of the *Second European Network Intelligence Conference (ENIC)* (pp. 114-121). IEEE Press.

Jonassen, D.H. (2000). *Computers as Mindtools for Schools*. *Engaging Critical Thinking*. Upper Saddle River, NJ: Prentice-Hall.

Hoppe, H. U., Erkens, M., Clough, G., Daems, O., & Adams, A. (2013). Using Network Text Analysis to characterise teachers' and students' conceptualisations in science domains. Proc. of the *2nd International Workshop on Teaching Analytics* (IWTA 2013) at LAK 2016, Leuven (Belgium), April 2013.

Krajcik, J. S., Blumenfeld, P. C., Marx, R. W., & Soloway, E. (1994). A collaborative model for helping middle grade science teachers learn project-based instruction. *The Elementary School Journal* 1994, 483-497.

Llinás, P., Haya, P., Gutierrez, M. A., Martín, E., Castellanos, J., Hernán, I., & Urquiza, J. (2014). ClipIt: Supporting social reflective learning through student-made educational videos. In *Open Learning and Teaching in Educational Communities* (Proc. of EC-TEL 2014) (pp. 502-505). Springer International.

Malzahn, N., Hartnett, E., Llinás, P., & Hoppe, H. U. (2016). A smart environment supporting the creation of juxtaposed videos for learning. In *State-of-the-Art and Future Directions of Smart Learning* (pp. 461-470). Springer Singapore.

Meyer, J. H. F. & Land, R. (2003) Threshold concepts and troublesome knowledge: Linkages to ways of thinking and practising within the disciplines. In Rust, C. (Ed.) Improving Student Learning - Theory and Practice Ten Years on. Oxford (UK), Oxford Centre for Staff and Learning Development (OCSLD).

Newman, M. E., & Girvan, M. (2004). Finding and evaluating community structure in networks. *Physical Review E*, 69(2), 026113.

Sawardecker, E. N., Amundsen, C. A., Sales-Pardo, M., & Amaral, L. A. N. (2009). Comparison of methods for the detection of node group membership in bipartite networks. *The European Physical Journal B*, *72*(4), 671-677.

Schön, D. A (1987) *Educating the Reflective Practitioner*. San Francisco, CA: Jossey-Bass Publishers.

Vosniadou, S. (2007). Conceptual Change and Education. Human Development, 50(1), 47–54.

Wasserman, S., & and Faust, K. (1994). Social Network Analysis: Methods and Applications. New York (USA): Cambridge University Press.

Wise, A. F., Cui, Y., & Vytasek, J. (2016). Bringing order to chaos in MOOC discussion forums with content-related thread identification. In *Proceedings of the Sixth International Conference on Learning Analytics & Knowledge* (pp. 188-197). ACM.

Zahn, C., Hesse, F., Finke, M., Pea, R., Mills, M., & Rosen, J. (2005). Advanced digital video technologies to support collaborative learning in school education and beyond. In Proc. of the *International Conference on Computer Support for Collaborative Learning* (CSCL 2005) (pp. 737-742). International Society of the Learning Sciences.