Supporting Incremental Formalization in Collaborative Learning Environments

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Abstract. Arguing that a varying level of formality needs to be offered in systems supporting collaborative learning, this paper proposes an incremental formalization approach that has been adopted in the development of CoPe_it!, a web-based tool that complies with collaborative principles and practices to provide members of communities with the appropriate means to manage individual and collective knowledge, and collaborate towards the solution of diverse issues. According to the proposed approach, incremental formalization can be achieved through the consideration of alternative projections of a collaborative workspace, as well as through mechanisms supporting the switching from one projection to another. Related features and functionalities are presented through an illustrative example.

Keywords: Collaborative Knowledge Building and Sharing, Incremental Formalization, Services for Technology Enhanced Learning, Problem Solving Support, Learning Communities and Distributed Teams.

1 Introduction

Argumentative collaboration, conducted by a group of people working towards solving a problem, can admittedly facilitate and augment learning in many ways, such as in explicating and sharing individual representations of the problem, maintaining focus on the overall process, maintaining consistency, increasing plausibility and accuracy, as well as in enhancing the group's collective knowledge [1-3]. Designing software systems that can adequately address users' needs to express, share, interpret and reason about knowledge during an argumentative collaboration session has been a major research and development activity for more than twenty years. Technologies supporting argumentative collaboration usually provide the means for discussion structuring and visualization, sharing of documents, and user administration. They support argumentative collaboration at various levels and have been tested through diverse user groups and contexts. Furthermore, they aim at exploring argumentation as a means to establish a common ground between diverse stakeholders, to understand positions on issues, to surface assumptions and criteria, and to collectively construct consensus [4].

However, when engaged in the use of these technologies through a software system supporting argumentative collaboration, users have to follow a specific formalism. More specifically, their interaction is regulated by procedures that

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prescribe and - at the same time - constrain their work. This may refer to both the system-supported actions a user may perform (e.g. types of discourse or collaboration acts), and the system-supported types of argumentative collaboration objects (e.g. one has to strictly characterize a collaboration object as an idea or a position). In many cases, users have also to fine-tune, align, amend or even fully change their usual way of collaborating in order to be able to exploit the system's features and functionalities. Such formalisms are necessary towards making the system interpret and reason about human actions (and the associated resources), thus offering advanced computational services. However, there is much evidence that sophisticated approaches and techniques often resulted in failures (see, for instance, [5, 6]). This is often due to the extra time and effort that users need to spend in order to get acquainted with the system, the associated disruption of the users' usual workflow [7], as well as to the "error prone and difficult to correct when done wrong" character and the prematurely imposing structure of formal approaches [8].

As a consequence, we argue that a varying level of formality should be considered. This variation may either be imposed by the nature of the task at hand (e.g. decision making, joint deliberation, persuasion, inquiry, negotiation, conflict resolution), the particular context of the collaboration (e.g. legal reasoning, medical decision making, public policy making), or the group of people who collaborate each time (i.e. how comfortable people feel with the use of a certain technology or formalism). The above advocate an incremental formalization approach, which has been adopted in the development of CoPe_it![1], a web-based tool that is able to support argumentative collaboration at various levels of formality. CoPe_it! complies with collaborative learning principles and practices, and provides members of communities engaged in argumentative discussions and decision making processes with the appropriate means to collaborate towards the solution of diverse issues. According to the proposed approach, incremental formalization can be achieved through the consideration of alternative projections (i.e. particular representations) of a collaborative workspace, as well as through mechanisms supporting the switching from one projection to another.

This paper focuses on the presentation of the above approach. More specifically, Section 2 comments on a series of background issues related to reasoning and visualization, as well as on related work. Section 3 presents our overall approach, illustrates the features and functionalities of CoPe_it! through a representative example and sketches the procedure of switching among alternative projections of a particular workspace. Finally, Section 4 discusses advantages and limitations of the proposed approach and outlines future work directions.

2 Background Issues

The representation and facilitation of argumentative collaboration being held in diverse settings has been a subject of research interest for quite a long time. Many software systems have been developed so far, based on alternative models of argumentation structuring, aiming to capture the key issues and ideas during meetings, and create a shared understanding by placing all messages, documents and reference material for a project on a "whiteboard" [9]. More recent approaches pay

[1] http://copeit.cti.gr

particular attention to the visualization of argumentation [10]. Generally speaking, existing approaches provide a cognitive argumentation environment that stimulates reflection and discussion among participants (a comprehensive consideration of such approaches can be found in [11]). However, they receive criticism related to their adequacy to clearly display each collaboration instance to all parties involved (usability and ease-of-use issues), as well as to the formal structure used for the representation of collaboration. In most cases, they merely provide threaded discussion forums, where messages are linked passively. This usually leads to an unsorted collection of vaguely associated positions, which is extremely difficult to be exploited in future collaboration settings. As argued in [12], “packages in the current generation of argument visualization software are fairly basic, and still have numerous usability problems”. Also important, they do not integrate, in most cases, any reasoning mechanisms to (semi)automate the underlying decision making processes required in a collaboration setting[2]. Thus, there is a lack of alternative formalization, consensus seeking and decision-making support abilities.

Various surveys of Computer-Supported Collaborative Learning (CSCL) environments also reveal much criticism on the solutions offered. For instance, it has been admitted that these solutions often require that users carry out activities that do not naturally belong to their work, or they support activities which are infrequent in normal work and do not help users to carry out their most frequent activities [15]; thus, such activities are often considered artificial or insignificant by users. The exploration of the possibilities to enrich CSCL environments with tools to support collaborative interaction, as reported in [16], led to the development of a collaboration management cycle from a systems perspective; the related reviewing of CSCL systems that instantiate the three stages of this cycle, namely mirroring, monitoring and advising, identified the fact that these systems address only a single stage (even partially, in most cases). In other words, the evolution of the collaboration management cycle is not appropriately supported. Other works reveal the necessity of CSCL systems to provide alternative representational features in order to demonstrate a significant effect on the learners’ collaborative knowledge building process and on learning outcomes [17].

Taking the above into account, we claim that an integrated consideration of various *visualization* and *reasoning* issues is needed in an argumentation-based collaborative learning context. Such an integrated consideration should be in line with *incremental formalization* principles. More specifically, it should efficiently and effectively address problems related to formality. As stressed in [6], “users want systems be more of an active aid to their work - to do more for them; yet they already resist the low level of formalization required for passive hypertext”. According to the proposed incremental formalization approach, problems related to formality have to be solved by approaches that (i) do not necessarily require formalization to be done at the time of input of information, and (ii) support (not enable or automate) formalization by the appropriate software.

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[2] Recently developed systems such as *Araucaria* [13] and *ArguMed* [14] address the issues of argument diagramming and formalization of argumentation. However, they do not comply with incremental formalization principles, while they were built to serve a particular context.

At the same time, the abovementioned integrated consideration should be also in line with the *information triage process* [18], i.e. the process of sorting and organizing through numerous relevant materials and organizing them to meet the task at hand. During such a process, users must effortlessly scan, locate, browse, update and structure knowledge resources that may be incomplete, while the resulting structures may be subject to rapid and numerous changes.

3 An Incremental Formalization Approach

The research method adopted for the development of the proposed solution follows the Design Science Paradigm, which has been extensively used in information systems research [19]. Moreover, the proposed solution is the result of action research studies [20] concerning the improvement of practices, strategies and knowledge of diverse collaborative learning environments. Building on the above, our main contribution lies in the formulation of an incremental formalization approach, and the corresponding development of a web-based tool for supporting argumentative collaboration as well as the underlying creation, leveraging and utilization of the relevant knowledge. Generally speaking, our approach allows for distributed (synchronous or asynchronous) collaboration and aims at aiding the involved parties by providing them with a series of argumentation, knowledge management and decision making features. Moreover, it exploits and builds on issues and concepts discussed in the previous section.

3.1 Analysis of Requirements

A series of interviews with members of diverse communities (from the engineering, management and education domains) has been performed in order to identify the major issues they face during their argumentative collaboration practices. These issues actually constituted a set of challenges for our approach, in that the proposed collaboration model and infrastructure must provide the necessary means to appropriately address them. Major issues identified were:

- *Management of information overload:* This is primarily due to the extensive and uncontrolled exchange of comments, documents and, in general, any type of information/knowledge resource, that occurs in the settings under consideration. For instance, such a situation may appear during the exchange of ideas, positions and arguments; individuals usually have to spend much effort to keep track and conceptualize the current state of the collaboration. Such situations may ultimately harm a community's objectives.
- *Diversity of collaboration modes as far the protocols followed and the tools used are concerned:* Interviews indicated that the evolution of the collaboration proceeds incrementally; ideas, comments, or any other type of collaboration object (i.e. knowledge items) are exchanged and elaborated, and new knowledge emerges slowly. When a community's members collaboratively organize information, enforced formality may require specifying their knowledge before it is fully formed. Such emergence cannot be attained when the collaborative environment enforces a formal model (i.e.

predefined types of knowledge items and relationships) from the beginning. On the other hand, formalization is required in order to ensure the environment's capability to support and aid the collaboration efforts. In particular, the abilities to support decision making, estimation of present state or summary reports benefit greatly from formal representations of the information units and relationships.

- *Expression of tacit knowledge:* A community of people is actually an environment where tacit knowledge (i.e. knowledge that the members do not know they possess or knowledge that members cannot express with the means provided) predominantly exists and dynamically evolves. Such knowledge must be able to be efficiently and effectively represented in order to be further exploited in a collaborative learning environment.
- *Integration and sharing of diverse information and knowledge:* Many resources required during a collaborative session have either been used in previous sessions or reside outside the members' working environment (e.g. in e-mailing lists or web forums). Moreover, outcomes of past collaboration activities should be able to be reused as a resource in subsequent collaborative sessions.
- *Decision making support:* Many communities require support to reach a decision. This means that their environment (i.e. the tool used) needs to interpret the knowledge item types and their interrelationships in order to proactively suggest trends or even calculate the outcome of a collaborative session (e.g. as is the case in voting systems).

3.2 Conceptual Approach

To address the above issues, our approach builds on a conceptual framework where formality and the level of knowledge structuring during argumentative collaboration is not considered as a predefined and rigid property, but rather as an adaptable aspect that can be modified to meet the needs of the tasks at hand. By the term formality, we refer to the rules enforced by the system, with which all user actions must comply. Allowing formality to vary within the collaboration space, *incremental formalization*, i.e. a stepwise and controlled evolution from a mere collection of individual ideas and resources to the production of highly contextualized and interrelated knowledge artifacts, can be achieved. As shown in Figure 1 (bottom part), this evolution is associated with a set of functionalities (namely, collection and sharing of knowledge items, exploitation of legacy resources, interrelation and evolution of knowledge items, informal / semiformal argumentation, informal / semiformal aggregation of knowledge items, semantic annotation of knowledge items, formal exploitation of knowledge items patterns, and formal argumentation and reasoning), which are ordered (from left to right) in terms of formality level.

In our approach, *projections* constitute the "vehicle" that permits incremental formalization of argumentative collaboration (see Figure 1). A projection can be defined as a particular representation of the collaboration space, in which a consistent set of abstractions able to solve a particular organizational problem during argumentative collaboration is available. With the term abstraction, we refer to the particular knowledge items, relationships and actions that are supported through a particular projection, and with which a particular problem can be represented, elaborated and - ultimately - be solved. Our approach enables the switching from a projection to another, during which abstractions of a certain formality level are transformed to the appropriate abstractions of another formality level. This transformation is rule-based; such rules can be defined by users and/or the facilitator of the collaboration and reflect the evolution of a community's collaboration needs. According to our approach, it is up to the community to exploit one or more projections of a collaboration space (upon users' needs and expertise, as well as the overall collaboration context).

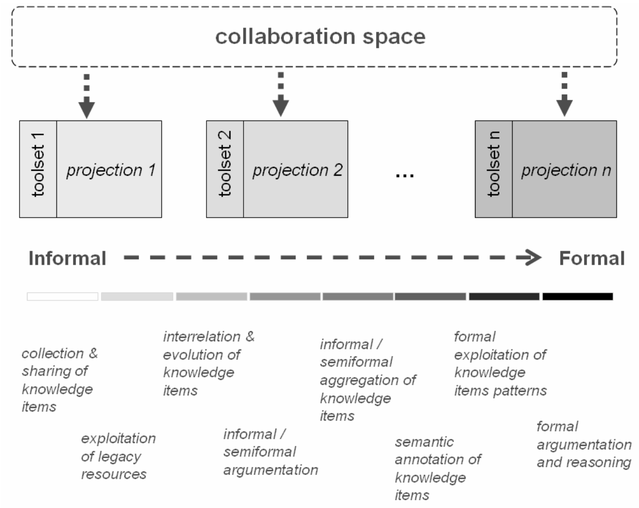

Fig. 1. The proposed incremental formalization approach[3]

Each projection of the collaboration space provides the necessary mechanisms to support a particular level of formality (e.g. `projection_1` may cover only needs concerning collection / sharing of knowledge items and exploitation of legacy resources, whereas `projection_n` may cover the full spectrum of the functionalities shown at the bottom part of Figure 1). The more informal a projection is, the more easiness-of-use is implied; at the same time, the actions that users may perform are intuitive and not time consuming (e.g. drag-and-drop a document to a shared collaboration space). Informality is associated with generic types of actions and resources, as well as implicit relationships between them. However, the overall context is human (and not system) interpretable. On the other hand, the more formal a projection is, easiness-of-use is reduced (users may have to go through training or reading of long manuals in order to comprehend and get familiar with sophisticated system features); actions permitted are less and less intuitive and more time consuming. Formality is associated with fixed types of actions, as well as explicit relationships between them. The overall context in this case is both human and system interpretable.

[3] Please visit http://tel.cti.gr/tzag/EC-TEL2007/ for a high-resolution version of all figures included in this paper.

As derives from the above, the aim of an informal projection of the collaboration space is to provide users the means to structure and organize knowledge items easily, and in a way that conveys semantics to them. Generally speaking, informal projections may support an unbound number of knowledge item types (e.g. comment, idea, note, resource). Moreover, users may create any relationship among these items (there are no fixed relationship types); hence, relationship types may express agreement, disagreement, support, request for refinement, contradiction etc. Informal projections may also provide abstraction mechanisms that allow the creation of new abstractions out of existing ones. Abstraction mechanisms include: (i) *annotation and metadata* (i.e. the ability to annotate instances of various knowledge items and add or modify metadata); (ii) *aggregation* (i.e. the ability to group a set of instances of knowledge items so as to be handled as a single conceptual entity; this may lead to cases where a set of knowledge items can be considered separately, but still in relation to the context of a particular collaboration); (iii) *generalization/specialization* (i.e. the ability to create semantically coarse or more detailed knowledge items in order to help users manage information pollution of the collaboration space); (iv) *patterns* (i.e. the ability to specify instances of interconnections between knowledge items of the same or a different type, and accordingly define "collaboration templates").

An informal projection also aims at supporting *information triage*. It is the informal nature of this projection that permits such an ordinary and unconditioned evolution of knowledge structures. While such a way of dealing with knowledge resources is conceptually close to practices that humans use in their everyday environment (e.g. their desk), it is inconvenient in situations where support for advanced decision making processes must be provided. Such capabilities require knowledge resources and structuring facilities with fixed semantics, which should be understandable and interpretable not only by the users but also by the tool. Hence, decision making processes can be better supported in environments that exhibit a high level of formality. The more formal projections of a collaboration space come to serve such needs.

3.3 Example

As mentioned in the introductory section, CoPe_it! is the tool enabling the proposed incremental formalization approach. It is a web-based tool that allows for both asynchronous and synchronous collaboration. The layout of the tool's main user interface is shown in Figures 2 and 3. Upon having the appropriate permissions, users may either create a new workspace for the needs of their community or collaborate with their peers in existing ones (there is also the option of maintaining private or public workspaces). The left hand side bar of the interface enables users to open a new browser, quickly search for related information (through Google and Wikipedia, or in the local repository), subscribe to RSS feeds, maintain a list of bookmarks, and be aware of other online members of their community.

Users may easily create and upload various types of knowledge items; these can be either existing multimedia resources (the content of which can be displayed upon request or can be directly embedded in the workspace) or dedicated item types such as *ideas*, *notes* and *comments*. Ideas stand for items that deserve further exploitation; they may correspond to an alternative solution to the issue under consideration and they usually trigger the evolution of the collaboration. Notes are generally considered as items expressing one's knowledge about the overall issue, an already asserted idea or note. Finally, comments are items that usually express less strong statements and are uploaded to express some explanatory text or point to some potentially useful information. Knowledge item types may change upon the evolution of the collaboration (e.g. a user that has asserted a particular comment may – at some point of the collaboration – elaborate it further and change its type to an idea).

All the above items can be interrelated by trouble-free user actions (as in the case of their creation and uploading, such actions are performed through the mouse). When interrelating items, users may select the color of the connecting arrow and provide (if they wish) a legend describing the interrelationship they conceive. These legends are intentionally arbitrary. An interesting feature of the tool is that it enables users to spatially arrange the uploaded items and cluster them in a meaningful way. Examples of such actions are given below; the spatial arrangement of items is also an easy task (users have just to click on an item and drag it to the desired position).

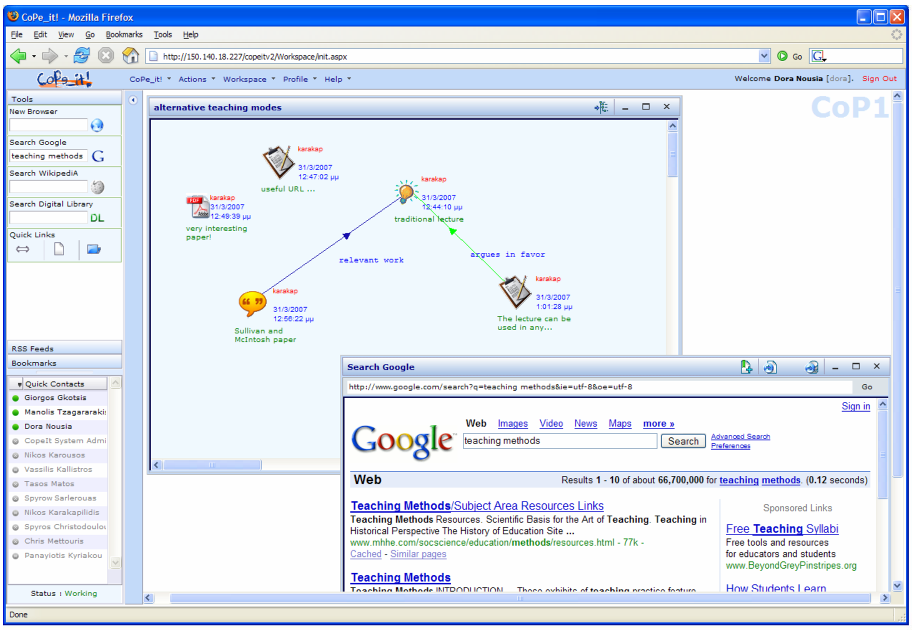

Fig. 2. A first instance of the collaborative workspace

To better present the features and functionalities of our approach, this subsection presents an illustrative example concerning real collaboration between members of a community of educators, aiming on considering *alternative teaching modes* to (potentially) reach a decision on which is the most appropriate one. Figure 2 illustrates an early instance of the collaborative workspace created for the needs of the above community (for the particular issue under consideration). As shown, only one user has contributed so far (nickname: `karakap`) by: (i) uploading on the workspace some useful resources (a "very interesting paper" and a "useful URL"), (ii) proposing the idea "traditional lecture" (as an alternative of teaching modes), and (iii) interrelating his idea with two additional items, one that clearly (according to him) argues in favor of the abovementioned proposal (to do so, he has uploaded the argument "The lecture can be used in any size class and is often the only option in large classes", and has related it - with a green arrow - to the idea "traditional lecture"), and a second one corresponding to related work ("Sullivan and McIntosh paper", which has been also related to his proposal).

Figure 3 illustrates a second instance of the collaborative workspace under consideration (the screenshot depicts only the workspace area). As shown, two more users (nicknames: `dora` and `tzagara`) have been contributed to the collaboration by: (i) proposing a second idea ("project work", asserted by `dora`), (ii) uploading additional related resources (e.g. a comment pointing to a "forum about motivation of students", a comment stating that "The instructor can spend more time with those students or groups who need attention", a note stating that "Because student participation is minimal, lecturing promotes passivity in students"), (iii) interrelating knowledge items (e.g. the note "By working together, students learn from one another and become less dependent on the instructor" to the idea about "project work", declaring that the former is an item that "argues in favor" of the latter, or the note "Because the lecture is teacher-centered, it tends to promote one-way communication and the notion that truth resides in the instructor" to the previously asserted idea about "traditional learning", also declaring that the former is

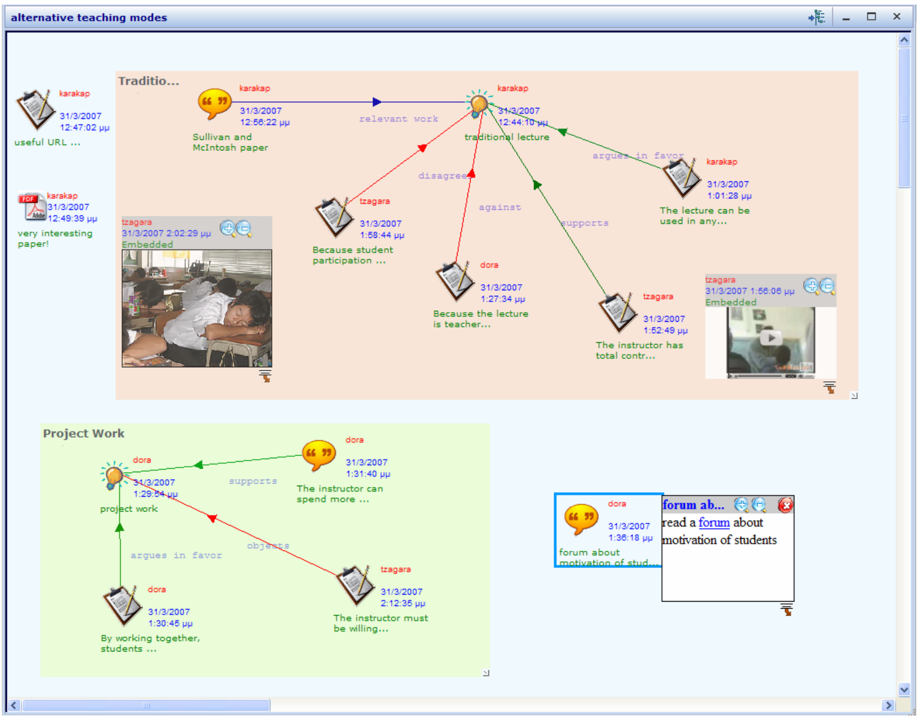

Fig. 3. A second instance of the collaborative workspace

"against" the latter), and (iv) uploading multimedia resources that are relevant to some knowledge items (in the instance shown, a video and an image have been embedded and placed intentionally close to the related items).

Beyond coloring of the arrows that interrelate knowledge items (in the example given, green arrows declare support whereas red ones declare opposition for the specific community), another visual cue that appears in Figure 3 concerns the colored rectangles that have been created by users to cluster related items (the two rectangles shown correspond to the two alternative ideas proposed so far). Although - at this instance - these rectangles are simply visual conveniences, they may play an important role during the switch to a more formal projection, enabling the implementation of appropriate abstraction mechanisms. Other visual cues supported in this projection may bear additional semantics (e.g. the thickness of an edge may express how strong a resource/idea may object or approve a teaching mode).

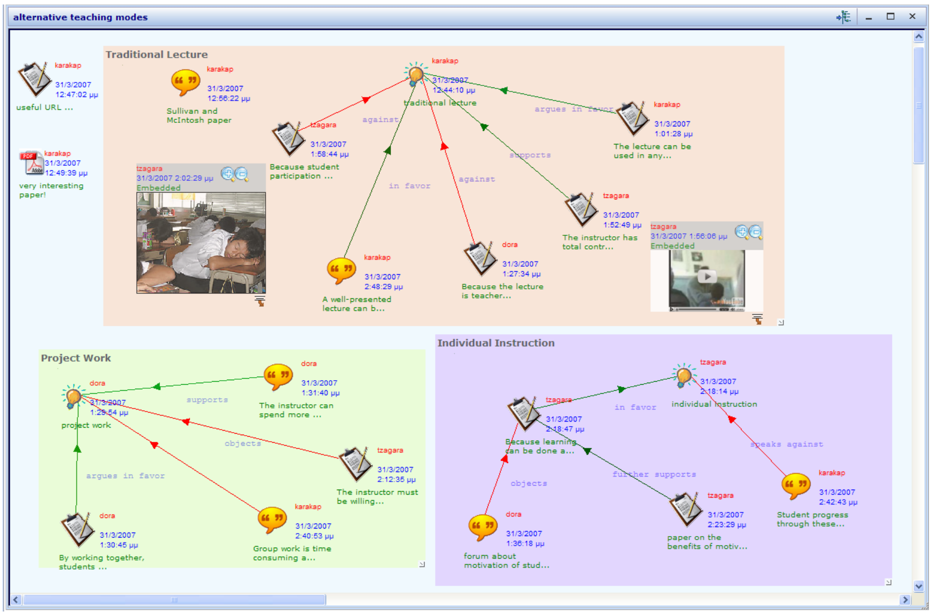

Fig. 4. The final state of the collaborative workspace

Figure 4 illustrates the final state of the collaborative workspace under consideration. As shown, a third idea has come up ("individual instruction", asserted by `tzagara`), while additional items have been uploaded and interrelated. The three color rectangles constructed aid users have a neat and quick view of the alternatives considered as well as the underlying argumentation. Since initially the process of gathering and sharing resources about the available teaching modes is unstructured, highly dynamic and thus rapidly evolving, the projection presented so far provides the most appropriate environment to support collaboration at this stage. The aim is to bring the session to a point where main trends crystallize, thus enabling the switch to a more formal projection (upon the participants' wish).

3.4 Switching Projections

The collaboration instances discussed above correspond to a projection that complies with the abovementioned information triage principles and allows incremental formalization (from a mere collection and sharing of knowledge items to exploitation of legacy resources, interrelation and evolution of knowledge items, and informal/ semiformal argumentation and aggregation of knowledge items)[4]. Such a projection could perfectly serve the needs of a particular community (for a specific context). However, some communities may have the need to further elaborate the knowledge items considered so far, and exploit additional functionalities to advance their argumentative collaboration. Such functionalities can be provided by other (more formal) projections that may enable the semantic annotation of knowledge items, the formal exploitation of collaboration items patterns, and the deployment of appropriate formal argumentation and reasoning mechanisms. As highlighted above, while an informal projection of the collaboration space aids the exploitation of information by users (user-interpretable view), a formal projection aims mainly at the exploitation of information by the machine (machine-interpretable view). Formal projections provide a fixed set of discourse element and relationship types, with predetermined, system-interpretable semantics.

Further elaborating the example of the previous subsection, let us assume that, at some point of the collaboration, an increase of the formality level is decided (e.g. by an individual user or the session's facilitator). In this case, there is the need to switch to a more formal projection, where knowledge items' and relationships' types have to be transformed, filtered out, or kept "as-is". The above are determined by the underlying visualization and reasoning model of the formal projection (consequently, this process can be partially automated and partially semi-automated). An instance of a projection enabling formal argumentation and group decision making is shown in Figure 5 (the screenshot depicts only the formal projection, which now appears in a separate window; the previous projection is still accessible). This formal projection adopts an IBIS-like formalism [21] and exploits functionalities of a previously developed argumentation support system [22]. It provides a structured language for argumentative discourse and a mechanism for the evaluation of alternatives. Taking into account the input provided by users, this projection constructs an illustrative discourse-based knowledge graph.

The knowledge items allowed in this projection are *issues*, *alternatives*, *positions*, and *preferences*. Issues correspond to problems to be solved, decisions to be made, or goals to be achieved. For each issue, users may propose alternatives (i.e. solutions to the problem under consideration) that correspond to potential choices. Positions are asserted in order to support the selection of a specific course of action (alternative), or avert the users' interest from it by expressing some objection. A position may also refer to another (previously asserted) position, thus arguing in favor or against it. Finally, preferences provide individuals with a qualitative way to weigh reasons for and against the selection of a certain course of action. A preference is a tuple of the form *[position, relation, position]*, where the relation can be "more important than" or

[4] The projection presented also allows for easy exploitation of existing web forums (items of a forum can be inserted in the workspace and further manipulated by users); this functionality is not shown due to space limitations.

"of equal importance to" or "less important than". The use of preferences results in the assignment of various levels of importance to the alternatives in hand. Like the other discourse elements, they are subject to further argumentative discourse. The above four types of items enable users to contribute their knowledge on the particular problem or need (by entering issues, alternatives and positions) and also to express their relevant values, interests and expectations (by entering positions and preferences). Moreover, the projection continuously processes the elements entered by the users (by triggering its reasoning mechanisms each time a new element is entered in the graph), thus facilitating users to become aware of the elements for which there is (or there is not) sufficient (positive or negative) evidence, and accordingly conduct the discussion in order to reach consensus.

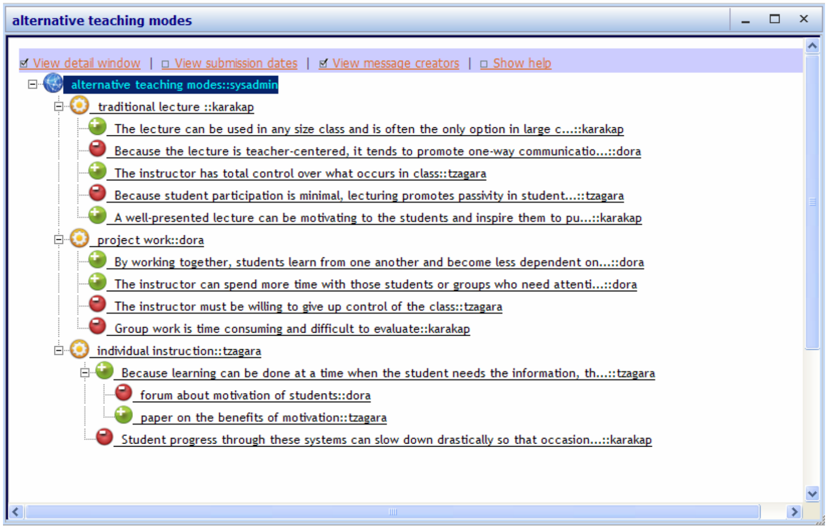

Fig. 5. Instance of a more formal projection

The instance shown in Figure 5 has been automatically built by transforming the projection instance of Figure 4 (the switching to this, more formal, projection has been initiated by the session's facilitator by requesting the related service from the tool). More specifically, the colored rectangles appearing in Figure 4 have been transformed to the alternatives of Figure 5 (each alternative is expressed by the related idea existed in the previous projection). Other knowledge items have been transformed to positions in favor or against (exploiting the coloring and the legends of the interrelating arrows)[5].

It is noted that, after the above transformation, the collaboration may continue at this projection, where users are able to exploit a richer set of features and functionalities that is associated to a higher formality level. For instance, further to the

5 A detailed explanation of the related transformation and graph structuring procedures, which may also take into account the semantic annotation of knowledge items, goes out of the scope of this paper.

argumentation-based structuring of a collaborative session, this projection integrates a reasoning mechanism that determines the status of each discourse entry, the ultimate aim being to keep users aware of the discourse outcome. More specifically, alternatives, positions and preferences of a graph have an activation label (it can be “active” or “inactive”) indicating their current status. This label is calculated according to the argumentation underneath and the type of evidence specified for them (“burden of proof”). Activation in this projection is a recursive procedure; a change of the activation label of an element is propagated upwards in the discussion graph. Depending on the status of positions and preferences, the mechanism goes through a scoring procedure for the alternatives of the issue (for a detailed description of the projection’s reasoning mechanisms, see [22]). At each discussion instance, users are informed about what is the most prominent (according to the underlying argumentation) alternative solution.

Alternative projections of a particular workspace should be considered (and exploited) jointly, in that a switch from one to the other can better facilitate the argumentative collaboration process. One may also consider a particular collaboration case, where decrease of formality is desirable. For instance, while collaboration proceeds through a formal projection, some discourse elements need to be further justified, refined and elucidated. It is at this point that the collaboration session could switch to a more informal view in order to provide participants with the appropriate environment to better shape their minds (before possibly switching back to the formal projection). Switching from a formal to an informal projection is also supported by our approach.

3.5 Other Issues

In addition to the above, our approach permits users to create one or more private spaces, where they can organize and elaborate the resources of a collaboration space according to their understanding (and their pace). Although private in nature, users are able to share such spaces with their peers. Moreover, each projection is associated with a set of tools that better suit to its purposes. These tools enable the population, manipulation and evolution of the knowledge item types allowed in that particular projection. There can be tools allowing the reuse of information residing in legacy systems, tools permitting authoring of multimedia content, annotation tools, as well as communication and management tools.

A first release of CoPe_it!, supporting various levels of formality using projections as the ones described above, has been already implemented. The tool makes use of Web 2.0 technologies, such as AJAX (Asynchronous JavaScript and XML), to deliver the functionalities of the different projections to end users. Based on these technologies, concurrent and synchronous collaboration in every projection is provided. Individual collaboration sessions are stored in XML format.

4 Discussion and Conclusion

Referring to [5], we first draw remarks concerning the advantages and limitations of the proposed approach against issues such as cognitive overhead and management of information overload, management of tacit knowledge, premature structure, and situational differences. Speaking about the first issue, we argue that our approach mirrors working practices with which users are well acquainted (they are part of their ordinary tasks), thus exhibiting low "barriers to entry". Moreover, it reduces the overhead of entering information by allowing the reuse of existing documents (mechanisms for reusing existing knowledge sources, such as e-mail messages and entries or topics of web-based forums, have been also integrated). In addition, our approach is able to defer the formalization of information until later in the task. This may be achieved by the use of the appropriate annotation and ontology management tools. In any case, however, users may be averted from the use of such (usually sophisticated) tools, thus losing the benefits of a more formal representation of the asserted knowledge resources. A remedy to that could be that such processing is performed by experienced users. One should also argue here that, due to the collaborative approach supported, the total overhead associated with formalizing information can be divided among users.

Speaking about management of tacit knowledge, we argue that the alternative projections offered, as well as the mechanisms for switching among them, may enhance its acquisition, capturing and representation. Limitations are certainly there; nevertheless, claiming that our approach promotes active participation in knowledge sharing activities (which, in turn, enhances knowledge flow), we expect that all four phases (i.e., internalization, socialization, combination and externalization) of the Nonaka's and Takeuchi's famous knowledge transformation spiral [23] can be leveraged. Reuse of past collaboration spaces also contributes to bringing previously tacit knowledge to consciousness.

Our approach does not impose (or even advocate) premature structure; upon their wish, participants may select the projection they want to work with, as well as the tasks they want to perform when working at this projection (e.g. a document can be tagged or labeled whenever a participant wants; moreover, this process has not to be done in one attempt). Decision making support issues are also addressed in a stepwise manner. Finally, considering situational differences, we argue that our approach is generic enough to address diverse collaboration modes and paradigms. This is achieved through the proposed projection-oriented approach (each projection having its own structure and rationale), as well as the mechanisms for switching projections (such mechanisms incorporate the rationale of structures' evolution).

As mentioned above, the proposed framework is the result of action research studies for collaborative learning improvement. It has been already introduced in various settings for a series of pilot applications. Preliminary results show that it fully covers the user requirements analyzed in Section 3.1; also, it stimulates interaction, makes users more accountable for their contributions, while it aids them to conceive, document and analyze the overall collaboration context in a holistic manner.

Concluding, we argue that the proposed approach is able to fully support the evolution of the collaboration management cycle (see Section 2) and provides the means for addressing the issues related to the formality needed in collaborative knowledge building and learning support systems. It aims at contributing to the field of social software, by supporting argumentative interaction between people and groups, enabling social feedback, and facilitating the building and maintenance of social networks. Future work directions include the extensive evaluation of CoPe_it! in diverse contexts and collaboration paradigms, which is expected to shape our mind towards the development of additional projections, as well as the experimentation with and integration of additional visualization cues, aiming at further facilitating and augmenting the information triage process.

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References

1. Koschmann, T.D.: Toward a dialogic theory of learning: Bakhtin's contribution to understanding learning in settings of collaboration. In: Hoadley, C.M., Roschelle, J. (eds.) Proc. of the CSCL'99 Conference, pp. 308–313. Lawrence Erlbaum, Mahwah, NJ (1999)
2. Andriessen, J., Baker, M., Suthers, D.: Argumentation, computer support, and the educational context of confronting cognitions. In: Andriessen, J., Baker, M., Suthers, D. (eds.) Arguing to learn: confronting cognitions in computer-supported collaborative learning environments, pp. 1–25. Kluwer Academic Publishers, Dordrecht (2003)
3. Ravenscroft, A., McAlister, S.: Designing interaction as a dialogue game: Linking social and conceptual dimensions of the learning process. In: Juwah, C. (ed.) Interactions in Online Education: implications for theory and practice. Routledge, pp. 73–90 (2006)
4. Jonassen, D.H., Carr, C.S.: Mindtools: Affording multiple representations for learning. In: Lajoiem, S.P. (ed.) Computers as cognitive tools II: Theory change, paradigm shifts and their influence on the use of computers for instructional purposes, pp. 165–196. Erlbaum, Mawah, NJ (2000)
5. Shipman, F.M., Marshall, C.C.: Formality Considered Harmful: Issues, Experiences, Emerging Themes, and Directions. Tech. Rep. ISTL-CSA-94-08-02, Xerox Palo Alto Research Center (1994)
6. Shipman, F.M., McCall, R.: Supporting knowledge-base evolution with incremental formalization. In: Proceedings of CHI'94 Conference, Boston, MA, April 24-28, 1994, pp. 285–291 (1994)
7. Fischer, G., Lemke, A.C., McCall, R., Morch, A.: Making Argumentation Serve Design. Human Computer Interaction 6(3-4), 393–419 (1991)
8. Halasz, F.: Reflections on NoteCards: Seven Issues for the Next Generation of Hypermedia Systems. Communications of the ACM 31(7), 836–852 (1988)
9. de Moor, A., Aakhus, M.: Argumentation support: from technologies to tools. Communications of ACM 49(3), 93–98 (2006)
10. Kirschner, P., Buckingham Shum, S., Carr, C.: Visualizing argumentation: software tools for collaborative and educational sense-making. Springer, London, UK (2003)
11. Karacapilidis, N., Loukis, E., Dimopoulos, S.: Computer-supported G2G collaboration for public policy and decision making. Journal of Enterprise Information Management 18(5), 602–624 (2005)
12. van Gelder, T.: Enhancing Deliberation through Computer Supported Argument Visualization. In: Kirschner, P., Buckingham Shum, S., Carr, C. (eds.) Visualizing Argumentation: Software Tools for Collaborative and Educational Sense-Making, pp. 97–115. Springer, London (2003)

13. Reed, C.A., Rowe, G.W.A.: Araucaria: Software for Argument Analysis, Diagramming and Representation. International Journal of AI Tools 14(3-4), 961–980 (2004)
14. Verheij, B.: Artificial argument assistants for defeasible argumentation. Artificial Intelligence 150(1-2), 291–324 (2003)
15. Lehtinen, E., Hakkarainen, K., Lipponen, L., Rahikainen, M., Muukkonen, H.: Computer Supported Collaborative Learning: A Review. In: Meijden, H., Simons, R., de Jong, F. (eds.) Computer supported collaborative learning in primary and secondary education. Final report for the EC Project 2017, pp. 1–46. Univ. of Nijmegen (2000), http://etu.utu.fi/papers/clnet/clnetreport.html
16. Soller, A., Martinez, A., Jermann, P., Muehlenbrock, M.: From Mirroring to Guiding: A Review of State of the Art Technology for Supporting Collaborative Learning. International Journal of Artificial Intelligence in Education 15, 261–290 (2005)
17. Suthers, D.: Representational Guidance for Collaborative Learning. In: Hoppe, H.U., Verdejo, F., Kay, J. (eds.) Artificial Intelligence in Education, pp. 3–10. IOS Press, Amsterdam (2003)
18. Marshall, C., Shipman, F.: Spatial Hypertext and the Practice of Information Triage. In: Proceedings of the 8th ACM Conference on Hypertext, Southampton UK, pp. 124–133. ACM Press, New York (1997)
19. Hevner, A.R., March, S.T., Park, J., Ram, S.: Design Science in Information Systems Research. MIS Quarterly 28(1), 75–105 (2004)
20. Checkland, P., Holwell, S.: Action Research: Its Nature and Validity. Systemic Practice and Action Research 11(1), 9–21 (1998)
21. Conklin, J., Begeman, M.: gIBIS: A tool for all reasons. Journal of the American Society for Information Science 40(3), 200–213 (1989)
22. Karacapilidis, N., Papadias, D.: Computer Supported Argumentation and Collaborative Decision Making: The HERMES system. Information Systems 26(4), 259–277 (2001)
23. Nonaka, I., Takeuchi, H.: The Knowledge-Creating Company. Oxford University Press, Oxford (1995)