Supporting collaborative learning interactions: an activity theory-based approach

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ABSTRACT: In this article, the author attempts to integrate existing work on supporting collaborative learning interactions within the activity theory perspective in order to provide insight into the features of the online collaborative process in a more consistent framework. In particular, the author presents the basic elements of this theory, focusing on a classification scheme of the collaboration mediating artefacts and their relevant roles. A series of collaborative interactions modelling approaches and technologies that realise artefacts from the entire above scheme are also presented. The verification of the efficiency of a supporting character mediation, as experimental uses have shown, proves the potentiality of the proposed integration. Moreover, it motivates a further elaboration of the functionality of the above artefacts across their classification scheme at a higher level of abstraction towards a more refined support by capturing the implicit characteristics of the collaborative interactions.

INTRODUCTION

The evolution of technology that supports collaborative learning is highly connected to learning theories that justify such design efforts. Within the sociocultural approach, Activity Theory (AT), as introduced by Leontiev, is proposed here as a framework for the analysis of a Web-based, asynchronous, written collaborative activity [1-4]. More specifically, such an activity can be modelled, according to AT, by an activity system as depicted in Figure 1a [5]. Within this system, collaboration takes place between subjects and a community, all sharing the same interest to perform the activity, according to predefined rules and division of labour, ie to transform an *object* (eg a case study) into an *outcome* (eg, a text that provides the solution to the case study problem(s)). Artefacts, ie tools in a broad sense that include real and mental objects, mediate the activity being subjects to transformations and carriers of the cultural characteristics of the community [6]. This transformation motivates the whole conscious activity [7]. This activity holds a dynamic character of parallel processes that take place at three levels according to the objects they are oriented to [6].

More specifically, the first level of this hierarchical structure, foresees the collaborative *activity* that is oriented to the *motive*, eg the text production. At the lower level, the *actions*, eg collaborative interactions, take place towards conscious *goals*, eg effective collaboration. Finally, the *actions* are realised by the *operations*, eg the mouse clicks that take place at the third level and are defined by the available *conditions* (eg the interface design).

Within a collaboration management system, the design of artefacts that describe the current and desired quality of the collaboration may serve the realisation of the necessary support at the collaborative interactions level towards an effective collaborative activity [8]. Thus, specific artefacts can follow the externalisation of subjects' cognitive processes that are expressed through collaborative interactions at the cognitive level [4]. Other facilitate the internalisation of feedback information they carry concerning the quality of the collaborative interactions at the metacognitive level [4][9]. At the latter level, the artefacts may enrich the subject's awareness of his/her emotional situation during collaboration and enhance his/her ability to apply strategies towards the improvement of collaborative interactions at the cognitive level. These strategies may also be externalised as meta-cognitive interactions and followed by artefacts.

From the above it is evident that cognitive and metacognitive procedures can be distributed to artefacts [10]. Thus, they can differentiate their mediating role and lead to their classification into four levels [11][12]. This is depicted in Table 1.

On the basis of the aforementioned collaboration management cycle, a supporting activity system may be developed in conjunction with the collaboration activity system, as depicted in Figure 1(b). Within the former, the subject and supporting system share the common goal of improving the quality of subjects' collaborative interactions towards a balance, which is expressed by the Balance of the Collaboration Activity (BCA) indicator [13]. The BCA, in turn, defines the division of labour in the collaboration activity system.

Motivated by the above, the present work focuses on presenting examples of supporting artefacts during asynchronous written collaboration towards the BCA (see Figure 1b) as seen from the AT perspective. More specifically, their examination within the above artefacts classification scheme sheds light on the intrinsic characteristics of collaborative interactions as seen from various perspectives.

Table 1: The classification of artefacts within an activity system.

Level	Class	Characteristics
1^{st}	The *what*	It contributes a *means* of achieving the outcome
2^{nd}	The *how to*	It contributes to the *understanding* of how to achieve the outcome
3^{rd}	The *why*	It *motivates* the achievement of the outcome
4^{th}	The *where to*	It provides the estimation of the next state of the activity in order to provoke the *evolution* of all the components of the activity system towards the achievement of the outcome.

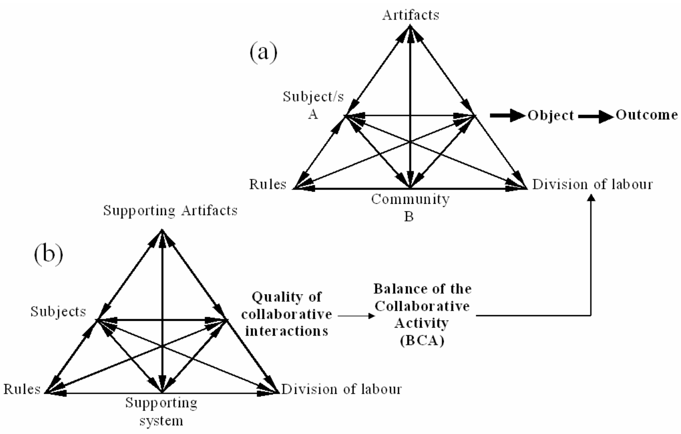

Figure 1: Activity systems for (a) collaboration and (b) the provision of support to collaborative interactions.

EXAMPLES OF ARTEFACT IMPLEMENTATION

The artefacts that are discussed here are embedded in the *Lin2k* tool [13]. This is used for Web-based asynchronous, written collaboration. More specifically, all of these artefacts hold a supporting character, ie they materialise the activity system presented in Figure 1b, which supports two collaborating subjects $n = A, B$ (Figure 1a).

Capturing the Data (the *What* Artefacts)

In general, these artefacts are physical, tangible devices that facilitate the sharing of the common *goal*. In the asynchronous written collaboration environment, examples of such artefacts include the elements detailed below.

One such example is the virtual space(s) where the collaboration takes place, eg interfaces of common sight that facilitate the subjects to follow the threads (history) of the collaboration.

Another example covers tools for communication like semi-structured individual interfaces (eg Figure 2) that materialise an artefact with a two-fold function in both the activity systems presented in Figure 1. In the first case (Figure 1a), it materialises a dialogue management system by allowing specific interactions to take place, whereas in the second case (Figure 1b), it contributes to archiving their characteristics.

Another example incorporates log files or databases for the logging of information concerning collaborative interactions, ie type of collaborative interactions (such as *proposal, contra-proposal, comment, clarification, agreement* and *question* in Figure 2) [13]. This also invovles their sequence and the level of the subject's mental activity they express, ie cognitive or metacognitive [13]. Further elaboration of these raw data leads to the development of artefacts of higher levels.

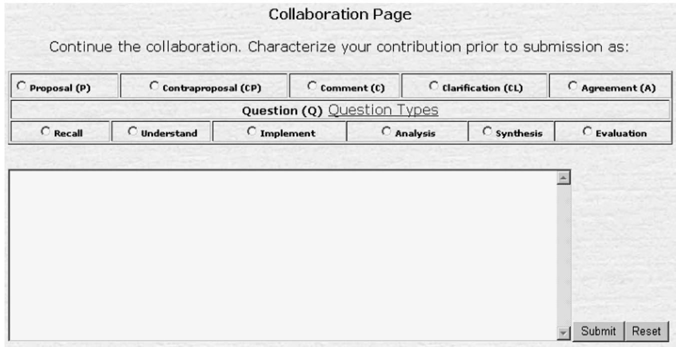

Figure 2: The *Lin2k* semi-structured communication tool showing an excerpt from the individual interface dedicated to collaboration.

Establishing a Common Vocabulary (the *How* Artefacts)

These tangible or intangible artefacts contribute to the realisation and use of the *what* artefacts by the subjects. In the collaboration system under consideration (Figure 1b), they refer to artefacts with an informative character that aim at the establishment of a common language between the community, ie the subjects and the system. Examples of such artefacts include information concerning the following:

- An explanation of the BCA as a goal;
- The rules that define the time intervals for the feedback provision by the system that lead to a successive sessions-concept of collaboration, namely *steps of collaboration*;
- A weighting system that differentiates the collaborative interactions on the basis of the cognitive effort that is employed for their preparation (eg a *proposal* is more highly weighted compared to an *agreement*);
- The interpretation of the feedback that is provided by the system in the form of specific indicators or depictions, eg Figure 3;
- The usage of the communication tools provided at the cognitive and metacognitive levels in order to facilitate the proper manipulation of relevant forms and interfaces by subjects during the collaborative procedure [13].

Motivating (the *Why* Artefacts)

The aim of these artefacts is to facilitate the achievement of the *goal*. An example in this direction is the modelling of the $n = A, B$ subjects' interactions in a way that provides information concerning the current quality of their collaborative interactions in the form of an indicator. In particular, a third-class artefact, namely C/M-FIS, was developed on the basis of fuzzy logic [13]. C/M-FIS managed to model the ambiguity of the linguistic description of an expert's evaluating system of the quality of collaborative interactions and provide the C_n^s indicator (see Figure 3a).

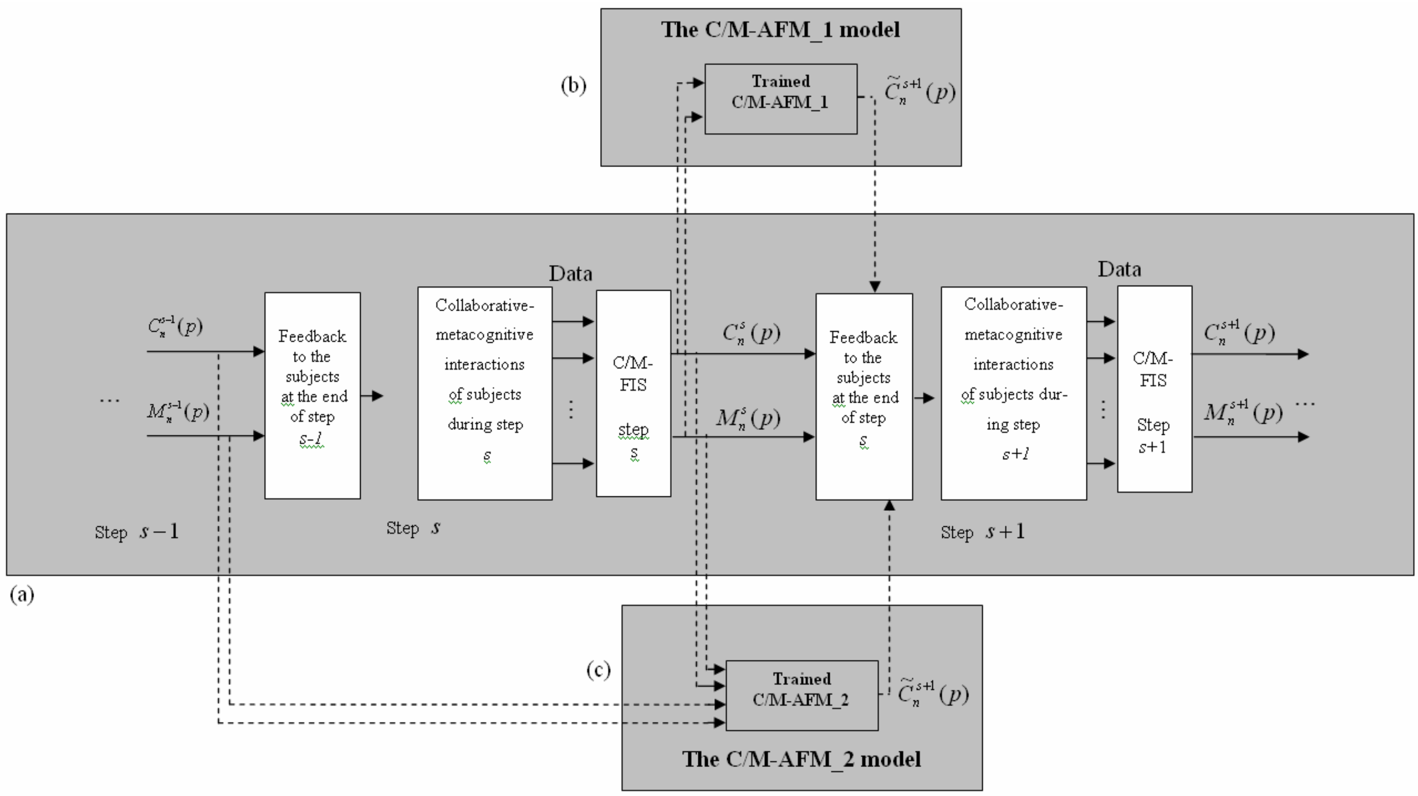

Figure 3: The integration of the *why* and *where to* artefacts within the *Lin2k* supporting activity system.

The C_A^s and C_B^s values were appropriately normalised in order to be aggregated up to 100%, the latter denoting the overall group (n=A,B) collaborative activity. Thus, a low percentage, eg of C_A^s, indicates the low contribution of A to the above activity as opposed to B, whereas a value of between 40% and 60% denotes the accepted zone of the BCA (Figure 4).

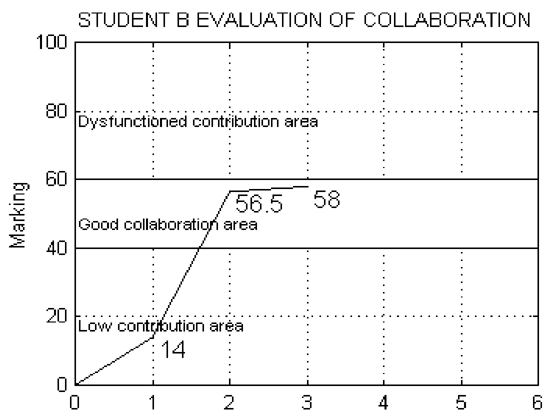

Figure 4: The depiction of the $C_B^{s=1:3}$ indicator values (%) and the BCA zone (marking 40-60%) is included in the feedback content to the subject at the end each step s.

Such information, compared to the BCA, is expected through internalisation to provoke an adjustment of the subject's collaborative strategy in the next step of collaboration [13]. The latter intention is explicitly expressed by the subject by filling in an appropriate metacognition form prior to entering the next step of collaboration. This form includes declarative sentences of *proper* collaboration and, upon selection, the improvement to specific aspects of collaboration is denoted. Raw data from this form are modelled, again through the C/M-FIS artefact, to output the M_n^s indicator (Figure 3a). The M_n^s values were also normalised in the range of 0-100% (corresponding to *no intention* to improve and to *intention for total improvement*, respectively). Within this range, the M_n^s value quantifies the intention of improvement in the forthcoming step according to the provided rules of *proper* collaboration. The divergence of the M_n^s and M_n^{s+1} indicators produces a further refinement of the feedback information (Figure 3a) that aims at the enhancement of the metacognitive strategies.

An alternative, yet with a similar aim to the above, is the development of artefacts that lead to the detection of those out-of-limits values of the C_n^s indicator in order to capture and make explicit the possible dissonance between subjects' collaborative activities and the motivation for its minimisation. In particular, in ref. [14], the use of the Quality Control Analysis (QCA) was employed for the development of an artefact of the same class. Through the upper and lower limits that are automatically defined through samples of the C_n^s and M_n^s values, which are acquired by experimental uses of the C/M-FIS, it specifies the accepted range of the absolute value $dC_{A,B}^s = \left|C_A^s - C_B^s\right|$. The latter serves as a measure of the divergence from the BCA and the QCA further refines the feedback content.

Another example of the third class artefact can be found in ref. [15], which, on the basis of the Lempel-Ziv algorithm, calculates a complexity indicator of the interactions turn-taking, proving an increase of its value when the feedback is provided.

Frustrating the Goal (the *Where to* Artefacts)

The prediction of human behaviour is quite a common situation in real-life contexts. When a *goal* is frustrated, it is then necessary to realise what to do next and set a new goal [6]. Keeping this analogy, when the goal of the collaborative activity under consideration, ie convergent to the BCA, is envisioned to be unsatisfactory, then adjustment procedures may be challenged. Following this direction, predictive models can be employed to provide the *where to* artefacts. An example of artefact of the *where to* level can be found in ref. [16].

In particular, fuzzy neural networks technology was used to train a network, namely C/M-AFM, upon historical data. This is aimed at modelling the relation between C_n^s and M_n^s, with $\widetilde{C}_n^{s+1}$ for all the steps, ie to model the implicit characteristic of the adopted collaborative strategies by the subject per step. Two scenarios were studied: the C/M-AFM_1 and C/M-AFM_2, respectively. These scenarios differed on the depth of the collaboration history used for the training (Figures 3b and 3c). Small differences were detected between the two scenarios through sufficient model validation procedures. A further refinement of the training procedure is expected to verify this finding. When trained, the C/M-AFM artefact can provide a real-time estimation of the forthcoming $\widetilde{C}_n^{s+1}$ value on the basis of the aggregation of the current step's collaborative and metacognitive strategies. Providing this estimation as feedback to the subject prior to step $s + 1$ (Figure 3a) is expected to support further the BCA *goal*.

CONCLUSIONS

An Activity Theory-based (AT) approach of supporting collaborative learning interactions is presented in this article, placing the features of the collaborative process in a more consistent methodological framework. In the light of the above methodological framework, the use of artefact classes is also proposed. Examples of the *what*, *how*, *why* and *where to* classes of artefacts, involving a range of enhanced processing/modelling techniques, are presented in order to prove the potentiality of the materialisation of all the levels of the proposed taxonomy within the AT framework.

Initial results show that the proposed framework can integrate a variety of approaches that are aimed at facilitating peer collaboration. Detailed information and indicative results of the presented techniques can be found in the cited references.

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