Adaptive Support for Collaborative Learning with IMS Learning Design: Are We There Yet?

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Abstract. This paper examines ways in which on-line collaboration in general, and on-line collaborative learning in particular, can be supported using existing and novel adaptivity techniques. In that context, a set of requirements that need to be met for providing adaptive support for collaborative e-learning is formulated. The IMS Learning Design specification is then assessed against these requirements, to determine whether it can serve as a sound basis for implementing the aforementioned types of adaptive support. The paper concludes that, although this specification is a promising one in this respect, it still lacks several features that would be vital in adaptively supporting collaborative learning.

Keywords: adaptivity, collaboration, e-learning, CSCL, IMS LD

1 Introduction

The proliferation of Internet- and Web- technologies in the last two decades has brought about major changes in practically all facets of human activity. This trend has already had tremendous impact in the field of education, where new teaching and learning paradigms have been established under the general "umbrella" of e-learning (or, to use an equally popular term, open and distance learning). New technologies have allowed for much richer learning experiences, as well as for the elimination of temporal and geographic barriers traditionally associated with learning activities. The strides achieved, however, have been accompanied by an inevitable decrease in the amount of face-to-face contact between instructors and learners, and especially between learners themselves, which has created new hurdles in the education process.

It is widely acknowledged that a large part of success of the learning process lies with the opportunities of learners to interact with others: groupwork, exchanging ideas, and helping each other (thereby learning themselves) are standard "classroom" practices. With limited real-world contact, learners have limited means for discovering other learners' capacities, skills, interests, strong and weak points, disposition towards teamwork, willingness to help, learning progress etc. Without such knowledge, learners cannot make informed decisions about everyday learning tasks like: whom to direct a question to; which person(s) have the complementary skills required to put together a group that can effectively work on a given task; when to contact them; etc.

Fostering exchanges between online students can also lead to social cohesion, and, more specifically, to a psychological sense of community [1]. The later has been shown to be a major factor in attaining study-related satisfaction [2], achieving successful learning outcomes [3], preventing student burnout [4], and decreasing dropout rates [5]. Research about distance-learning has also revealed that interactions among students and instructors increase the effectiveness of learning [6] and is beneficial both to individuals and to institutions [7].

This paper examines ways in which on-line collaboration in general, and on-line collaborative learning in particular, can be supported using existing and novel adaptivity techniques. To this end, a set of requirements that need to be met for providing adaptive support for collaborative e-learning will first be discussed. We will then examine which of these requirements are met by the IMS Global Learning Consortium's Learning Design specification (IMS LD [8]). IMS LD is specifically targeted because it is, at the moment, the only widely known and used specification that provides a language for modeling group learning activities. The conclusion of the presented analysis is that IMS LD needs to evolve further before it can be used for adaptive collaboration support and some of the required evolution steps represent a considerable departure from the current form of the specification.

2 Adaptive Support for Collaborative Learning

In the context of this paper, adaptive collaboration support refers to adaptive support in learning processes that involve communication between multiple persons (and, therefore, social interaction), and, potentially, collaboration towards common objectives [9]. Such support is intended to contribute towards intelligent and automated approaches to online learning that are in line with modern learning theory, which increasingly emphasizes the importance of collaboration, cooperative learning, communities of learners, social negotiation, and apprenticeship in learning [10].

The theme of adaptive collaboration support lies at the crossroads of two areas of work that have been evolving independently until now: Computer-Supported Collaborative Learning and Adaptive / Intelligent Learning Systems.

Computer-based and computer-supported cooperative / collaborative systems have emerged to enable people to perform tasks and carry out activities synergistically, over temporal and geographic distances [11]. Computer-Supported Collaborative Learning (CSCL) arose from research on CSCW and emerged as a separate field of study in the early 90s. Put briefly, CSCL is focused on how collaborative learning supported by technology can enhance peer interaction and work in groups, and how collaboration and technology facilitate sharing and distributing of knowledge and expertise among community members.

The field of adaptive e-learning has grown out of work on Intelligent Tutoring Systems, amalgamated with progress in the area of user-adaptive systems, as applied in computer-supported e-learning. Current systems that adaptively support collaboration maintain models for a large number of users, and use the information in these models to facilitate the establishment of collaboration activities, as well as to support ongoing collaboration itself. User modeling has been applied in connection with several (partially overlapping) types of collaboration: in computer-supported learning environments (see, e.g., [12]); as a means to provide adaptive social awareness support (see, e.g., [13]); as way of providing "intelligent help" for complex tasks (see, e.g., [14]); putting human expert into the loop as way of avoiding some of the difficulties associated with fully automatic adaptive help systems; in environments for computer-supported cooperative work within organizations (see, e.g., [15]); etc. Adaptive learning environments are increasingly being made available on the web, with representative examples including ELM-ART [16] and SQL TUTOR [17].

Adaptive techniques that have been used in the area of collaboration support can be broadly categorized into ones that address the establishment of collaboration in the first place (e.g., group establishment) and ones that support the collaboration process itself [18]. Although these categories are by no means mutually exclusive, they do exhibit significant differences in their adaptation determinants and constituents. We will outline these in the rest of this section, and use them later on as a guide for assessing the sufficiency of IMS LD for implementing adaptive collaboration support.

The analysis that follows focuses specifically on *collaboration* support. It is assumed, however, that information regarding *individual learner activities* is also available to the adaptation components and algorithms where this might be needed (e.g., it is assumed that systems maintain a learner model per individual learner).

Adaptive Support for the Establishment of Collaboration

Systems in this category are typically based on the learners' personal- and learning-characteristics and preferences, either explicitly stated by the users themselves, or observed / inferred during their interaction with the system [19] [20]. A lot of these adaptation determinants can be readily represented in user and learner models following existing practices and utilizing existing specifications such as the IMS Learner Information Package specification [21]. This is in large part due to the fact that this category of systems does not need to explicitly model the activities and performance of groups, but rather to facilitate their formation; thus, modeling only individuals is an essentially viable approach. At the same time it can be assumed that at least part of the information stored in the user- / learner- profiles is automatically derived by the system through observation. Examples of cases where this would be desirable include situations where: manual maintenance of the information by the users themselves would be tedious (e.g., recording their progress through learning materials); objective assessments must be derived (e.g., performance of learners in a test); etc.

More recent approaches to adaptively supporting the establishment of collaboration go further than described above, to take into account: (a) historical activities of learners in collaboration contexts; and (b) the learners' current engagement in collaborative activities, from long-term asynchronous ones, to short-term synchronous ones. This allows for the implementation of a wide range of adaptation strategies, from ones that "couple" users based on their propensity to collaborate and participativity, to ones that take into account a learner's current collaboration load and availability (including instantaneous load, such as when the user is participating in a live audio session).

The type of information described above cannot readily be stored in traditional user- or learner- profiles, unless it has already been processed and summarized so that it can be expressed in the form of user properties. Additionally, because of the sheer amount of involved information, it is not reasonable to expect users to explicitly provide the related information to the system, especially since the system is evidently "present" when the related activities take place (but the users should maintain control over the system's inferences in most if not all cases).

Based on the above, we can identify a number of high-level requirements as far as adaptation in this category is concerned:

A1. Capability to automatically collect / infer and model *user- and learner- profile data* of individual learners, and provide access to said data for adaptation algorithms.

A2. Capability to automatically collect / infer and model *collaboration activity data* for individual learners, and provide access to said data for adaptation algorithms; this may also entail observing the *activity of groups as collective entities* in the process. Activity data can be modeled in many alternative ways. This requirement is not prescriptive as to the modeling approach used, as long as the system can provide at least aggregate information about the activities of individual learners, grouped by activity category and learning context (e.g., messages a student posted to a project-related forum, as a percentage of total messages posted in that forum for the duration of the project).

A3. Capability to represent and employ *algorithms / strategies* that govern how learner information is used to *identify appropriate collaboration partners*. Note that the act of identifying collaboration partners is here considered separate from how the resulting information is used further by the system. In existing systems, it is typically used directly for partner recommendation. Many alternative uses are possible though: determining the "fit" of teams established directly by their members; identifying missing skills in a group; making a prognosis about potential problems a group may encounter based on its members' characteristics; etc.

A4. Although not an absolute requirement, it would also be desirable for the system to allow for *alternative policies for / approaches to group initiation*. Examples of such policies include: assign a peer to assist a learner that is assumed to be encountering difficulties while taking an online knowledge practice test; cluster course participants into groups to tackle a question posited in a class setting; etc.

Adaptive Support during the Collaboration Process

Systems that support the collaborative learning process itself need first and foremost to model the said process and the performance of groups within it, based on both learning and social characteristics [22]. Although work to introduce adaptivity in this area is limited at the moment (arguably due to the non-trivial effort involved), it is rather straightforward to identify the constituents and determinants of adaptation, if we accept that, in the ideal case, the adaptive system should be able to take over the role that a human facilitator might play in the process.

Starting then with the adaptation constituents, at the first level, the system would need to be able to observe the collaboration activities of learners. However, in this case, such observations need to be a lot more elaborate than what was described above. Specifically, the system would need to be able to identify / discern activities with higher accuracy; it would also need to identify the services and artifacts that these activities involve and their state (e.g., a document being jointly edited by group members on a wiki). At a second level, the system should be able to: (a) determine whether any expressed constraints about the process are observed by the group as a whole, or by the individuals within it, and (b) identify patterns of group activity in a semantically meaningful way so that they can be acted upon if and when necessary.

Further to the above, and in contrast to systems only concerned with facilitating group formation, in this case we also need to address the modeling of groups themselves as multi-faceted entities. Properties such as the group's creation policy, creation time, termination policy, assets available to its members, roles of the members, etc., all need to be explicitly represented and can be used as the basis for adaptation. Additionally, the system may need to maintain more elaborate group models, as is often for example the case in group recommenders [23], where collective properties of the group's members also need to be maintained.

Moving on to adaptation constituents, and carrying on with the analogy of an equivalent to an external to the group human facilitator, we can identify several aspects of the collaboration process where a system might be able to intervene: varying the group size; recommending or assigning (changes in) roles for participants; modifying the activity structure (e.g., by adding / removing / reordering tasks); determining the availability of elements (including activities, services and artifacts); etc. The challenge here, of course, is not to pick out the aspects of collaborative activities that can be modified, but rather: (a) to make sure that such changes can be made fully at run-time, and (b) that the changes made do not have detrimental effects on the learning process, or the activities that have already been completed or are under way.

Based on the above, we can derive another list of high-level requirements for adaptation in this category of collaborative learning support:

- B1. Capability to maintain *models of groups*, including collective properties of the groups' members, automatically collect / infer information for these models, and provide access to them for adaptation algorithms.
- B2. Capability to maintain *models of group activities*, including the roles of participants, the services used, the artifacts produced, etc.
- B3. Capability to *guide the collaboration process*, using the aforementioned models of group activities.
- B4. Capability to automatically collect / infer and model *collaboration activity data* of group members, including services used and artifacts used and / or produced, and provide access to said data for adaptation algorithms. This requirement is an extension of requirement A2, in that it dictates not only aggregate information about the activities of a group and its members to be available, but rather more detailed access to individual activities and groupings thereof.
- B5. Capability to *identify group activity patterns in a semantically meaningful way* (e.g., patterns that may indicate conflicts amongst team members)
- B6. Capability to represent and employ *algorithms / strategies* that govern how collaboration information is used to *identify appropriate interventions*
- B7. Support for enabling the above *adaptation algorithms to modify any aspect of the collaboration process* (including aspects of its participants, and other participating entities). Such support may be constrained, and will typically also involve assessing the *validity* of the resulting process specification if the requested modifications were to be applied.

3 The IMS Learning Design Specification

The IMS Learning Design specification [8] evolved out of the Educational Modelling language (EML) developed by the Dutch Open University OUNL [24]. IMS LD is a learning process modeling language, fashioned on the theatrical play metaphor (e.g., with plays, actors, roles, etc.), and intended to formally describe any design of teaching-learning processes for a wide range of pedagogical approaches [24][25].

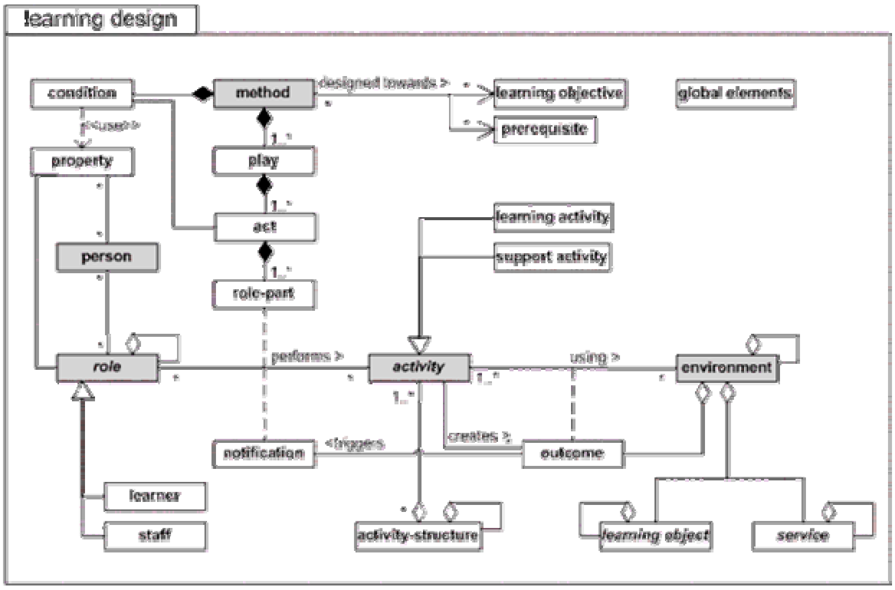

Fig. 1. Conceptual model of overall Learning Design (from [8])

The specification consists of three levels [8][26]. Each level itself provides specific features to the educational information embodiment, called the Unit of Learning. Level A provides method, plays, acts, roles, role-parts, learning activities, support activities and environments; Level B provides properties, conditions, calculations, monitoring services and global elements; and Level C provides notifications. Every level is built on the previous one. Level A is the main part of the specification, and forms the basis of any Unit of Learning. Level B adds powerful features to create more complex e-learning lesson plans. And, Level C provides an activity oriented triggering system. Fig. 1 provides an overview of the IMS LD conceptual model that results from the combination of all three layers.

Although the basic structure is provided by Level A, it is actually the elements of Levels B and C which provide the necessary mechanisms and affordances for adaptation, as they combine properties with conditions and other features that encourage and make more flexible the content and the learning flow [26].

According to the literature, IMS LD can support six main types of adaptation [27]: Learning flow based, content based, interactive problem solving support, adaptive user grouping, adaptive evaluation and changes in run-time (although, as we will see in the next section, the capacity of the specification in terms of adaptive user grouping can be strongly contested).

It should be noted that this specification is not intended to be used in isolation. IMS LD can be closely integrated with, or often relies on, other IMS-issued specifications. For instance, IMS LD does not directly support the representation of learning / skill tests – but can integrate them through the IMS Question and Test Interoperability specification [28]; the case is similar for maintaining learner profile information through the IMS LIP specification [21].

The IMS LD specification is targeted in this analysis for a number of interrelated reasons. Firstly, widely used Learning (Content) Management Systems (LMS) are very likely to support at least a selection of e-learning standards; at the same time, they are rather unlikely to include any custom provisions or mechanisms exclusively intended to support adaptivity [29]. Therefore, if one is aiming at wide-spread support for adaptivity in the context of collaborative e-learning, one should channel related research efforts through appropriate standards. Given that IMS LD is the only e-learning specification at the moment that addresses the topic of collaborative learning, and has gained traction with major LMS, it was felt that it constitutes the most effective vehicle for ensuring future complying systems have the features in place that would allow for adaptive collaborative e-learning to become a reality.

4 Adaptive Collaboration Support Using IMS LD

IMS LD has been acknowledged as a language with strengths in specifying *personalized learning* and *asynchronous cooperative learning*. However, IMS LD provides insufficient support to model group-based, synchronous collaborative learning activities [30]. Caeiro et al. [31] criticized IMS LD regarding CSCL purposes and suggested a modification and extension of the specification. The suggested changes are, however, restricted to the role- and method- parts of the specification. Hernandez et al. [32] suggested adding a special type of service, called “groupservice” to extend the capacity of IMS LD. It has been argued that such an extension at service level, rather than at activity level, cannot appropriately capture the characteristics of collaborative learning activities [30].

In the context of research examining IMS LD as a language in which CSCL scripts[1] can be formally expressed, Miao et al. [30] identify weaknesses of the specification in the following areas: modeling groups, modeling artifacts, modeling dynamic features, modeling complicated control flow, and modeling varied forms of social interaction. We will summarize and examine these in turn, along with other IMS LD problems and omissions that are more specific to adaptivity in the context of collaborative e-learning, to determine the extent to which they affect adaptive collaboration support prerequisites.

– *No built-in support for modeling groups*: IMS LD does not provide primitives for directly representing groups of learners. In some simple cases, groups may be pos-

[1] According to O’Donnell & Dansereau [33] a collaboration script is a set of instructions specifying how the group members should interact and collaborate to solve a problem.

sible to represent using roles and custom global properties[2]. This is not a viable solution in all cases though, as it requires an exhaustive enumeration of roles and sub-roles (to represent groups and sub-groups) at design time. Another problem the system cannot explicitly identify groups / sub-groups at run-time, which severely limits the system's capacity to support inter- / intra- group collaboration appropriately. A related problem is that, in IMS LD, roles are assigned to persons before running a unit of learning and remain unchanged within the life cycle of the run. As far as adaptivity is concerned, because it means we can't really add a person to a group dynamically, and it also means we can't dynamically change the role of a person, which removes a very important constituent from the adaptation "arsenal". In fact, as observed in [27], once a run starts, we can only add and remove users from roles, .but this is about all the flexibility available.

- *No built-in support for modeling artifacts*: A second major deficiency of IMS LD is in modeling artifacts. In learning processes, actors use and generate artifacts such as a vote, an answer, an argument, or a design. In IMS LD, an artifact can only be modeled as a property of the person / role / etc., which creates the artifact. In fact, attributes of the artifact (like type, status, creator, contributors, etc.) can also only be expressed as properties. Additionally, to ensure the validity of the representation, one would have to write elaborate rules governing the said properties and their values with very poor reusability. It's also worth mentioning that IMS LD doesn't support any array-like data structure, which also complicates the representation of collective artifacts.
- *Poor support for modeling dynamic features*: The dynamic manipulation of the process model in IMS LD is effected through "read" operations which return the state of process elements, and "write" operations which modify them (e.g., change-property-value, hide / show elements, and send notification). In [30] this requirement is posited as "more write operations need to be provided". To reformulate that statement, IMS LD has little support for effecting changes to the learning process model once that model participates in a "live" session. It is, as we shall see, one of the most prominent stumbling blocks when attempting to combine adaptivity in the specification under discussion.
- *Poor support for modeling complicated control flow*: A fourth major problem is how to model complex process structures. IMS LD provides the *play, act, rolepart*, and *activity-structure* elements to model structural relations at different levels. Primarily linear structured learning / teaching processes with concurrently executable activities can be modeled. However, as Caeiro et. al. [31] pointed out, while modeling network structures, the linear structure of a play with a series of *acts* introduced a great rigidity. Limited support to modeling non-linear structural relations among activities can be achieved through the use of custom conditions and notifications, likely at the expense of the comprehensibility and maintainability of the final result. From the perspective of adaptation, this is a major shortcoming, as it eliminates an entire category of potential adaptation determinants.

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[2] Some representational facilities are available in IMSLD to support creation of groups (min-persons and max-persons) and although assignment of users to groups can be achieved, fully automatic on-the-fly creation of groups may require additional representational devices.

- *Poor support for modeling varied forms of social interaction*: As already mentioned, IMS LD uses a metaphor of a theatrical play to model learning / teaching processes. A play consists of a sequence of acts and within an act there is a set of role-parts. These role-parts can run together in parallel. Role-parts enable multiple learners, playing the same or different roles, to do the same thing or different things concurrently on the same act. If a group of people performs a synchronous activity, IMS LD enables them to use a conference service but provides no means at activity level to support collaboration. In collaborative learning processes, it is quite usual that people with the same or / and different roles perform a shared activity through direct or indirect interaction. While making the joint effort, people with different roles may have different rights to interact with other roles and the environment. In particular, it can not be clearly modeled by using IMS LD whether and how people collaborate, because people may work in a variety of social forms: Individually, in an informal group, in sub-groups, in a group as a whole, or in a community.
- *No exchange of information across Units of Learning*: This is a very limiting factor, as different UoLs can only "communicate" and interoperate through global properties, and employing entirely custom approaches.
- *Poor modeling of services and their characteristics*: The set of services that the specification includes by default is very limited and incorporate hardly any support for retrieving or settings advanced characteristics. In fact, the use of "tools" / "services" is seen as opaque from the perspective of the specification (i.e., the specification is not at all concerned about the inner workings of said tools and services, or how learners employ them). For instance, conference types are limited to "synchronous", "asynchronous" and "announcement"; this is clearly an immensely insufficient level of detail if adaptations are to be supported. Additional services can be "namespaced"[3] into the specification, but this is cumbersome technically and presumes that a de facto standard set of services and respective attributes emerges through bilateral agreements between specification adopters.
- *Acts within plays cannot be re-sequenced or structurally modified*: Although, formally speaking, this can be treated as a special case of the "poor support for modeling complicated control flow" mentioned earlier, it is detrimental enough for adaptivity that it is worth isolating and highlighting by itself. The IMS LD specification explicitly forbids changing the sequence of acts in a play, including doing so using conditions. It is also very difficult, if at all possible, to use a one-act-per-play approach, because in that scenario activities have to be independent of each other. Also, plays are handled differently per the specification, being made available concurrently (but without the possibility to express interconnections and interdependencies). Finally, it is also not possible to make activities available that are not already predefined in the act. Removing activities can be simulated by making them invisible though. This leads inevitably to having to exhaustively list all alternative configurations that can lead to the desired adaptive states through showing and hiding only, which quickly leads to an impractical (if at all possible) to manage combinatorial explosion of possible initial play configurations.

[3] Refers to the use of XML namespaces to create additions to an existing XML-based specification (like IMS LD).

– *Notifications cannot be added / removed (enabled / disabled) dynamically*: This simply means that the cause and effect relationships of learners' activities cannot be modified adaptively, based for example on the current collaboration context, or any other factors derived from the adaptation determinants. And this, again, is yet another lost opportunity to extend automated support to the learners.

It is important, at this point, to realize that all the above problems point directly to three characteristics of IMS LD: (a) absence of a run-time component of the specification (which describes what should happen and how at runtime, like the SCORM Run-time Environment specification [34]); (b) absence of an event model allowing for registration by event subscribers, and / or direct polling of individual event sources; (c) very limited support for modifying the collaboration process once a "run" of a UoL has started. These are arguably the main directions in which work needs to be directed in order to evolve the IMS LD specification in one that can fully support activity-oriented collaboration support in e-learning settings. To get a feeling about the effect that solving these issues will have, consider that solving items (a) and (b) above, would provide full bidirectional communication between the hosted learning resources and the runtime environment.

5 Conclusions

Based on the preceding section, we can now outline the extent to which IMS LD meets the adaptation requirements that were set forth in section 2 above. In short, the IMS LD specification is well thought out and allows for a considerable variety of dynamic modifications of learning activities (e.g., hiding and showing activities, environments, etc.) With some provisions, several of the basic mechanisms for adaptation at the hypertext level are possible. Nevertheless, the specification has important weaknesses which prevent its direct use in adaptive collaboration support scenaria at the moment. Some of these changes (e.g., the addition of a runtime environment specification) are major steps, and may require considerable effort and time to attain.

The results are summarized in the following table. It is hoped that the analysis elaborated upon herein, along with provided coarse outline of required research steps, will stimulate interesting discussions at the workshop, and spur additional work in this very new and very interesting field in the future.

Table 1. IMS LD vs. Requirements for adaptively supporting collaborative learning.

Id.	***Description***	***IMS LD support***	***Explanation***
A1	Maintain user- and learner-profile data	Yes	Through associated specifications that can be "collocated" – such as the IMS / LOM Metadata, and the IMS LIP specifications
A2	Maintain data about collaboration activity and activity of groups as collective entities	Minimal	Minimal information about tools and services employed by learners. No appropriate "companion" specifications. No explicit representation of groups.

Id.	*Description*	*IMS LD support*	*Explanation*
A3	Support algorithms / strategies that identify collaboration partners	Some	Conditions, expressions and notifications allow for a reasonably powerful embedded "if-then-else" style rules, with some limited event-based triggering as well. More involved algorithms have to be implemented externally and communicate their results through global variables
A4	Support alternative policies for / approaches to, group initiation	No	Even when using "roles" to simulate groups, users have to be assigned to roles at the beginning of a run, and assignment cannot be done automatically
B1	Support the modeling of groups (as entities)	Minimal	Groups cannot be directly modeled, except through the misappropriation of the "role" element
B2	Support the modeling of group activities	Some	Good support for learning activities of multiple individuals. But: no (real) groups – see above; no support for modeling artifacts; and, inflexible activity structures.
B3	Guide collaboration based on process specification	Some	No provisions for checking if or when expected activities take place (no runtime model, and no event model either).
B4	Maintain collaboration activity data	No	Not part of the specification at the moment. An amendment could specify how such data can be accessed, leaving it up to the runtime system how to collect and store it.
B5	Support the identification of group activity patterns in a semantically meaningful way	No	Not possible without group activity models and collaboration activity data.
B6	Support alternative algorithms / strategies to identify possible and appropriate interventions	Some	Same as A3, but here external algorithms (e.g., for pattern matching) more likely. Interventions can be identified, but most of them not really applied at the moment (other than simple hiding / showing, etc.)
B7	Enable adaptation algorithms to modify any aspect of the collaboration process	Minimal	The collaboration process specification can only be changed in very few ways once a run starts at the moment.

Acknowledgements. The work reported in this paper has been partially supported by the following projects: (a) Socrates Minerva "Adaptive Learning Spaces" (ALS) project (229714-CP-1-2006-1-NL-MPP) -- http://www.als-project.org; (b) "Adaptive Support for Collaborative E-Learning" (ASCOLLA) project, supported by the Austrian Science Fund (FWF; project number P20260-N15).

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