# On the construction of adaptable visualizations of communities and learners

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**Abstract.** This paper presents ADVICE (Adaptable Visualization for CommunitiEs), a Web-based system which assists learners to develop asynchronous discussions according to the Practical Inquiry Model. In particular, ADVICE allows learners to characterize their peers' contributions providing a set of indicators that represent the various stages of the Practical Inquiry Model and combinations. In this way, learners are expected to acknowledge the stages of an effective discussion and adapt accordingly their contribution to the discussion. ADVICE further supports this metacognitive process by providing several adaptable visualizations. This paper presents the adaptable visualizations that ADVICE provides and discusses how these might be useful in a learning design context.

**Keywords.** learning design, learning analytics, community of inquiry, adaptability, self-reflection, metacognition

## 1 Introduction

Online discussion systems have been widely adopted to promote collaborative learning. In this direction, research in Learning Analytics (LA) deals with transformation of discussion raw data into meaningful information [1], [2], [3] and Various LA tools have been developed [3], [5]. These tools exploit a wide range of techniques such as text mining [6], social network analysis [5], statistics [3], information visualization [7], etc.

Our primary observation regarding the existing tools is that most of them are exclusively dedicated to the teachers and only a few are accessible by the learners. Specifically, information visualization, as a LA technique [], can be used to encourage reflection as it aims to make raw data available to assist users interpret various aspects of learning. However, despite the emerging recognition of the importance of visual learning analytics for learners [9], [10], [11], [12] this is still more typically aimed at

instructors or other stakeholders such as policymakers or educational leaders [11]. [12].

Another issue is the learners' minimal access to the tools. It is claimed that learners receive little support in visualizing and analyzing their activities [3]. Additionally, the variety of data indicators that represent learners' interaction, need to be described intuitively and contribute with a friendly graphical interface. However, some current tools provide just an overview of users' interactions and often in a unique representation. Such deficiencies are likely to transform data visualization and analysis in a time-consuming and less effective activity [3].

Except from the data that are gathered most usually for analysis (eg. navigation data) and are created as a result of users' learning activities, there are also data that evolve consciously effort from learners. It has been stated [3] that this distinction between unconscious and conscious traces of learners corresponds with low level-high order cognition because conscious traces require a degree of reflection (content of messages, comments, ratings, etc).

Design of effective e-learning strategies and activities as, first of all, a conscious and planned process of generating new ideas, requires theoretical guidance. Community of Inquiry framework (CoI) conceptualizes community in effective asynchronous discussions and has been used for supporting collaborative learning design activities [13]. In CoI the discussions, through conscious and continuum effort, aim to fulfill a specific purpose which in this case could be a learning design activity or, even more, every phase of this activity.

In the attempt of overcoming the above issues, we present the ADVICE (Adaptable VIsualization for CommunitiEs) learning analytics tool, which enables users to collaborate through asynchronous discussions and visualizes the cognitive development of the discussion and also users' cognitive development so as to export effective learning designs. Its design rationale is based on Community of Inquiry framework. It is integrated in the authoring environment of INSPIREus, which aims at cultivating learning design skills [14].

## 2 Learning Design and Practical Inquiry

In this paper we investigate community's cognitive development through asynchronous discussions focusing on collaborative learning design tasks. A main issue is that in collaborative learning designs, individual summative assessment fails to properly capture the individual contribution to the team and to acknowledge the learning processes involved [15]. On the other hand, online discussion systems have been widely adopted to promote collaborative learning and research has emerged on the effectiveness of asynchronous discussion activities on learning design for supporting collaboration [16]. Through asynchronous discussions, the members of a team have the opportunity to reflect in a deep way about how they design activities and learning objects.

The complete Learning Design life cycle [17], from conceptualization of the design where designers reflect about their educational context and objectives, to authoring and to implementation, combines the iterative structure of educational design research with the principles of inquiry learning [18].

Indeed, every phase of the LD life cycle requires new ideas expressed, synthesis and implementation of a final solution (meaning Practical Inquiry's phases) which leads to the next phase of LD cycle. This process often requires practical inquiry based circular renegotiations through LD cycle phases as to go forward to final learning design outcomes. Practical Inquiry [19] describes cognitive presence which is the critical presence of CoI as it reflects the intellectual climate and is related with the facilitation of critical reflection and discourse.

It is applicable in various blended settings, including online discussion forums and there is also evidence of its effectiveness on learning design outcomes [13]. It assumes that effective online learning, especially higher order learning, requires the development of the community, and this is a critical challenge in the online environment.

Moreover, the usefulness of awareness of the natural cycle of the learning process, as it is described by Dewey [19], is emphasized in order for the learner to regulate the learning process effectively. In addition, the interpretation of an online discussion through this model provides great opportunities to extend the knowledge presented [20].

## 3 ADVICE: Design Rational

### 3.1 Overview

ADVICE is a LA visualization tool which is implemented in the discussion forum of INSPIREus [21] for reflecting the users' perspective for the development of the practical inquiry [19] of the community and/or the individuals comprising a community. It captures log data from asynchronous discussions such as number of composed messages, and also qualitative data like each learner's perspective for the type of contribution of his/her and his/her peers' messages on the asynchronous discussion. In this way, each learner has the opportunity to co-interpret on discussion information.

In real time, the tool analyzes these data and presents to the user (learner or instructor) an image of the development of the cognitive process through the discussion according to the inquiry cycle. It is carefully designed to be accessible by users who are not computer specialists so as not to need technical support in using the particular tool.

The interface of ADVICE is adaptable, allowing users to choose between manually filling the visualization parameters and selecting them from a preset list. The user can choose to see perspective of specific groups of users and also their cognitive progress in the discussion. It is avoided to reveal individual's data due to privacy and ethical issues. In this way, the learner is able to reflect on the community's perspective for

his own cognitive progress or to compare his perspective for the cognitive progress of the community in relation to the community's perspective. The learner will become aware of his own actions by reflecting on them and by comparing his/her reflections to the one of his/her colleagues and potentially alters his behavior. Garrison [22] suggests that "the inquiry process can be greatly facilitated with metacognitive awareness of the inquiry cycle… not to mention the ultimate goal of self direction and learning to learn.", and this is the main aim of ADVICE.

### 3.2 Practical Inquiry

ADVICE is based on practical inquiry as the last is proposed by Dewey [19]. Practical inquiry model is a widely respected model. It is represented by a cycle (see Fig. 1) which is initiated with the perception of a need and then proceeds to "exploring for relevant knowledge, constructing a meaningful explanation or a solution, and finally resolving the dissonance through action"[23]. Practical Inquiry includes four phases (triggering event, exploration, integration and resolution) that describe cognitive presence, the one of the three elements of Community of Inquiry [19]. Cognitive presence has been study mostly because the awareness of phases of inquiry on learning can be useful in understanding and selecting specific strategies and activities [23].


**Fig. 1.** The Practical Inquiry cycle

### 3.3 Learning Analytics Process for ADVICE

According to the reference model of learning analytics [8], the overall LA process is often an iterative cycle and is generally carried out in three major steps: (1) data collection and pre-processing, (2) analytics and action, and (3) post-processing.

**Data collection and pre-processing.**

This step is critical to the successful discovery of useful patterns from the data and also allows transforming the data into a suitable format that can be used as input for a particular LA method.

INSPIREus provides learners the option to communicate asynchronously through forums. These forums have been extended with the ADVICE tool. In forum, every user (instructor or learner) can classify every learner's message according to nine categories which reflect the Practical Inquiry cycle. The design of this coding scheme has been tested for its validity with sufficient results [IN PRESS].

As it is proposed for CoI content analysis [24], the unit of analysis In ADVICE is the message. A common issue is that very often one message reflects more than one phases of practical inquiry. In CoI methodology more than one researcher code the same content for later comparison and reliability analysis. After that, the coders discuss about their codings in order to end to one final negotiated coding for each message. But after negotiation, loss of data is observed, due to the transformation of each individual coder's perspective. This issue arose also in the first research carried out for the coding scheme design [24]. For this reason, the redesigned proposed coding scheme offers choices for each particular phase of the inquiry process and also for combinations of them in cases that the user recognizes to a message, characteristics of more than one phase.

ADVICE tracks:

a) qualitative data: learners' and instructors' coding for every learner's post, as well as

b) quantitative data: how many times a student has viewed the Forum threads, how many times a student has viewed the discussion Forum and how many times a student has added a post.

Through a preprocessing stage, ADVICE calculates metrics of contribution, cognitive level and participation to the discussion for each member of the community.

In [13] it has been shown evidence for significant correlation of participation metric and the metric of contribution to resolution which is the most demanding cognitive phase. For this reason participation metric was selected as a quantitative measurement in a CoI.

Cognitive presence model has been successful in measuring the developmental nature of the learning process across disciplines. The cognitive demands may well also increase as learners are expected to contribute ideas and share their thoughts. ADVICE aims to measure individual's position into the cognitive development of the discussion. Considering the theoretical background of a collaborative community of learners, it is difficult to understand an individual isolated from the community.

The first qualitative measurement, "cognitive level", represents how many phases the learners' messages reflect. There are learners who post messages belonging only to exploration phase or only to resolution phase and there are learners who post messages that each reflects to a different phase of cognitive presence which means that the learners gradually assume greater responsibility to match the increased requirements of online discussion.

The second qualitative measurement "contribution" which represents individual's position into the discussion cannot ignore the learner's messages on every phase of

cognitive presence in relation to his/her peers. The aim of this metric is to distinguish a learner who has contributed a large proportion of messages in the discussion for a specific phase of cognitive presence in relation to his/her peers.

The system analyses the qualitative data in order to calculate the following metric for each learner's cognitive level:

Learner_cognitive_level =

1, if the learner's messages reflect one phase of cognitive presence according to group's median coding,

2, if the learner's messages reflect two phases of cognitive presence according to group's median coding,

3, if the learner's messages reflect three phases of cognitive presence according to group's median coding,

4, if the learner's messages reflect four phases of cognitive presence according to group's median coding.

The system analyses the qualitative data in order to calculate the following metrics for each learner's contribution:

Learner_contribution = a*contribution_to_triggering +b*contribution_to_exploration + c*contribution_to_integration + d*contribution_to_resolution (1)

where:

1. contribution to triggering event: the percentage of messages posted by a learner in relation to the messages of the community and, according to the group's median coding, they belong to phase 1 (triggering event),
2. contribution to exploration: the percentage of messages posted by a learner in relation to the messages of the community and, according to the group's median coding, they belong to phase 2 (exploration),
3. contribution to integration: the percentage of messages posted by a learner in relation to the messages of the community and, according to the group's median coding, they belong to phase 3 (integration),
4. contribution to resolution: the percentage of messages posted by a learner in relation to the messages of the community and, according to the group's median coding, they belong to phase 4 (resolution)

The a, b, c, d weights reflect each factor's importance for the particular task and the administrator is able to determine their value according to the design and scope of the discussion.

Then, the system analyses the quantitative data in order to calculate for each learner, the metric of his/her participation:

Learner_participation= d*time_spent_forum_view_threads + e* time_spent_forum_view_discussion +f* time_spent_forum_add_post (2)

where:

1. time_spent_forum_view_threads: factor reflecting how much time a learner spends to view the Forum threads,
2. time_spent_forum_view_discussion: factor reflecting how much time a learner spends to view the discussion Forum,
3. time_spent_forum_add_post: factor reflecting how many how much time a learner spends to add a post.

The d, e, f weights reflect each factor's importance for the particular task and the administrator is able to determine their value according to the design and scope of the discussion.

**Analytics and action –Adaptable Visualization.**

ADVICE provides learners with a complete view of the cognitive development of the asynchronous discussion based on the users' codings.

ADVICE currently provides two visualizations of the cognitive progress of the discussion and learners' contribution and cognitive level, allowing learners to intervene and adapt them by selecting the source of data to reflect on or compare with.

Figure 2 provides a representation from the main screen of ADVICE tool which is divided into three different areas: (1) the discussion overview area, (2) the area with the options of categories of users who code the discussion and, (3) the area with the options of categories of users whose messages have been coded.

1 The discussion overview area

In particular, the discussion overview area depicts data on users' codings of the asynchronous discussion messages. For each message of the discussion (X axis), an indication of the median coding of the learners' codings and/or the instructors is provided. The median coding is selected as a representative coding of the community (group of learners) because [IN PRESS] demonstrated that statistical median coding of learners coding for every message of the discussion had a significant high positive correlation with the coding that the researchers (experienced coders) have selected for the discussion. The values in axis Y are 1 to 9 according to the values that have been proposed in Data Collection and Preprocessing section and that follow the practical inquiry process.

2 The categories of users (learners and instructors) who coded the messages of the discussion

Fig. 2 shows the options that are provided to the user so as to see how specific categories of users had coded each message of the discussion (see Fig. 2 area 2). These categories are: users with specific characteristics like type of user: Community, instructor, the learner himself, and the other learners. For the other learners there are three different criteria: a) ranking of learners depending on their cognitive contribution in the asynchronous discussion (High contribution (the first 50% of the learners), Low contribution (the rest of the learners)), and b) ranking of learners depending on their participation in the asynchronous discussion: (High participation (the first 50% of the learners), Low participation (the rest of the learners)).

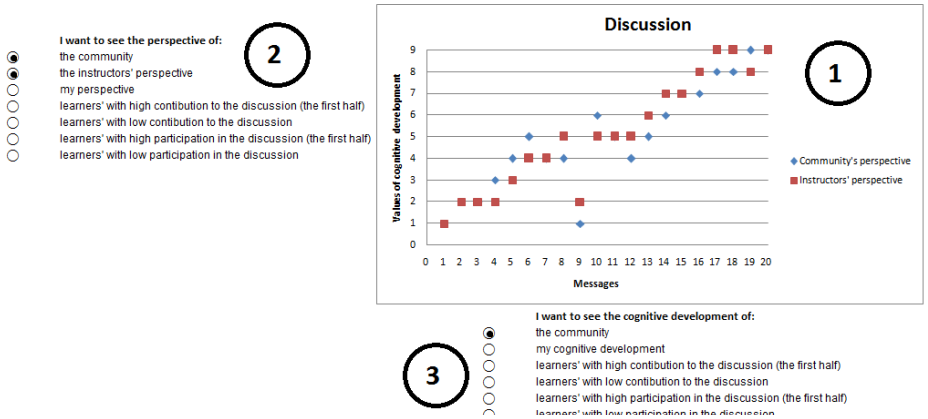


**Fig. 2.** (1) Visualization of the cognitive progress of the discussion, (2,3) Adaptability options

In this way, if the user chooses from area 2 "I want to see the perspective of: the community" and also "I want to see the perspective of: The instructors'" the user will see the coding choices of the instructors for the discussion in relation to community's coding (see Fig. 2).

3. The categories of learners whose messages have been coded

Fig. 2 shows the options that are provided to the user so as to see how the messages of specific categories of users had been coded (see Fig. 2, area 3). These categories are: users with specific characteristics like type of user: Community, the learner himself, and the other learners. For the other learners there are two different criteria: a) ranking of learners depending on their cognitive contribution in the asynchronous discussion (High contribution (the first 50% of the learners), Low contribution (the rest of the learners)) and b) ranking of learners depending on their participation in the asynchronous discussion: (High participation (the first 50% of the learners), Low participation (the rest of the learners)).

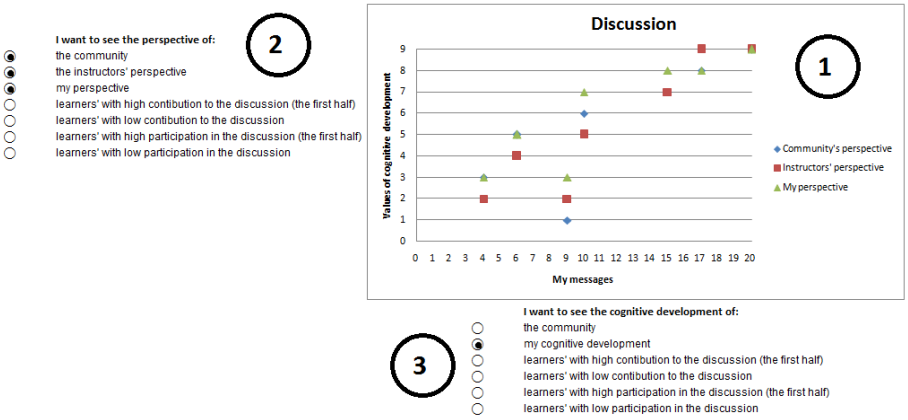

**Fig. 3.** (1) Visualization of the cognitive progress of the discussion, (2,3) Adaptability options , Example of visualization according to specific user's choices

In this way, if the user chooses from area 2 "I want to see the perspective of: "the community", "the instructors' perspective" and "my perspective" and from area 3 "I want to see the cognitive development of: My cognitive development", the user can see which is the community's, the instructors' and his own perspective for his own cognitive development (see Fig. 3).

Additionally, if the user chooses from area 2 "I want to see the perspective of: My perspective" and also "I want to see the perspective of: learners' with high contribution to the discussion" and from area 3 "I want to see the cognitive development of : learners' with high contribution to the discussion" the user will see the cognitive development of learners with hog contribution according to their but also according to the user's perspective in the same chart (see Fig. 4).

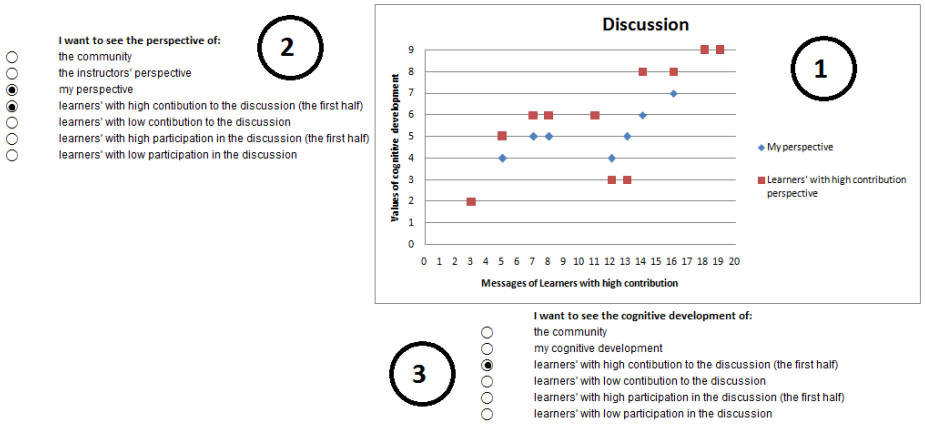


**Fig. 4.** (1) Visualization of the cognitive progress of the discussion, (2,3) Adaptability options. Example of visualization according to user's specific choices

According to the user's options, the combinations of visualization aspects may vary.

Another visualization provided to users is the star chart depicted in Figure 5. Every learner is able to see his own star chart in forum screen and in the overview discussion screen.

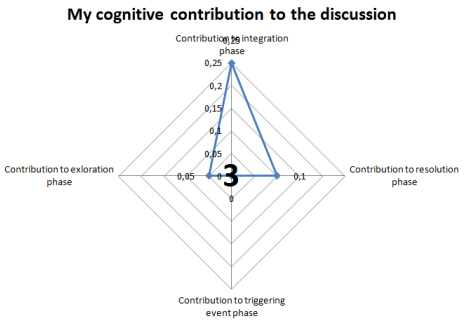


**Fig. 5.** Visualization of learner's contribution to the discussion and learner's cognitive level

In order to represent multivariate data like contribution to each phase of cognitive presence, we use the star chart also known as radar or spider chart. Each ax represents a different variable, meaning contribution to a specific phase of cognitive presence. The center is the minimum value for each variable and the ends represent the maximums. So if we draw a connecting line from one variable to the corresponding spot on the next axis we will formulate a star (or radar or spider web). In the center of the star chart there will also be the cognitive level of the learner measured as it is described in the preprocessing step of the reference model of learning analytics.

**Post-processing.**

Post – processing step will be held at the completion of ADVICE. In this paper we focus on the first two stages of the cycle.

The design of ADVICE has resulted from the continuous process of the steps of the reference model of learning analytics. At the step of post-processing it has been evaluated the coding schema that is proposed in the present study with sufficient results. For the next post-processing step, the ADVICE has to be evaluated in practice, in order to assess the effectiveness of the cognitive development of the learner within the community and therefore the cultivation of metacognitive skills.

## 4 Conclusion

In this paper we presented the ADVICE tool that aims at visualizing several aspects of a discussion such as each learner's perspective for the cognitive progress of a discussion, as well as the cognitive progress of each learner according to the other learners' perspective.

In this way, ADVICE each learner's contribution to the construction of the learning design outcomes and also to offer a deeper look in each learner's cognitive development through the learning design activities.

The approach adopted is based on the Practical Inquiry Model enabling learners' to classify their own, peers but also instructors' messages during an asynchronous discussion. Self, peer and instructors' messages coding process involves learners into the inquiry process and provides awareness and metacognition, aspects that are central to successful inquiry.

The implementation of ADVICE is in progress and the next step is the evaluation of the tool's effectiveness.

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