# Encouragement of Collaborative Learning Based on Dynamic Groups

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**Abstract.** We propose a method for creating different types of study groups with aim to support effective collaboration during learning. We concentrate on the small groups which solve short-term well-defined problems. The method is able to apply many types of students' characteristics as inputs, e.g. interests, knowledge, but also their collaborative characteristics. It is based on the Group Technology approach. Students in the created groups are able to communicate and collaborate with the help of several collaborative tools in a collaborative platform called PopCorm which allows us to automatically observe dynamic aspects of the created groups. The results of these observations provide a feedback to the method for creating groups. In the long term experiment groups created by our method achieved significantly better results in the comparison with the reference method (k-means clustering).

**Keywords:** CSCL, Collaboration, Group Technology, Groups

## 1 Introduction

Research in Computer-Supported Collaborative Learning (CSCL) domain can be grouped into systematic and dialogical approaches [4]. The systematic approach concerns the creating of models describing how the specific features of technological systems support or constrain collaboration, reasoning, knowledge representation, and structure of discourse [3]. On the other hand, the dialogical approach considers learning as a social-based activity. Therefore, we should pay appropriate attention to the group formation process which can significantly influence collaboration and thus, it is possible source of many improvements how to support effective collaboration.

In this paper, we deal with the dialogical approach, especially with the encouragement of students in collaborative learning by creating dynamic short-term study groups and design a collaboration platform which allows these groups to collaborate efficiently. The reason to follow this goal is the fact that we do not know what makes collaboration really effective and therefore how to join the students into effective groups. Thus, if we want students to collaborate effectively we should help them find appropriate collaborators.

## 2 Method for Creating Dynamic Groups

Recently, several methods and techniques were applied to group formation, e.g. ontologies, genetic algorithms, agent-based methods or methods for socially intelligent tutoring [8]. These methods usually use only one source of information about students and do not consider actual context, i.e. characteristics of the collaboration. Also they suppose that a teacher knows which attributes make collaboration more effective.

One prospective approach to group formation is based on Group Technology. According to Selim, et al. [6] Group Technology (GT) is an approach to manufacturing and engineering management that helps manage diversity by capitalizing on underlying similarities in products and activities. One application of the GT approach in manufacturing is a so-called Cellular Manufacturing. Groups of machines should be located in close proximity in order to produce a particular family of similar parts and thus minimize production and transfer time [2]. Several types of methods are described in [6] to solve the problem of cell formation. The most appropriate for us are procedures based on cluster analysis, especially array-based clustering techniques.

The basic idea of our method is derived from the GT approach because it solve similar problem as we have to solve to reach our goal. Analogy between domain entities can be easily found. It is possible to replace a machine with a student, a part with a characteristic, assignment of parts to the machine with assignment of characteristics to the student, and a family of similar parts with a set of related characteristics. Moreover, we can find this analogy also in goals; instead of optimizing machine production we need to optimize collaboration process.

The proposed method consists of two main processes:

1. *Group Formation* takes different personal or collaborative characteristics as inputs and creates study groups. Personal characteristics can be student's knowledge, interests, or any other personal characteristics (e.g. age, gender). We can obtain these characteristics from many sources, such as existing user models, social networks or questionnaires. Furthermore, characteristics can include collaborative aspects, such as students' collaborative behavior;
2. *Collaboration* allows students of created groups to participate on task solving via a collaboration platform which provides appropriate collaboration tools together with functionality for observation groups' dynamic aspects which are used as one of inputs in the method for creating groups.

Input data to our method are composed of two matrices: a matrix of related characteristics and a matrix of assignments of characteristics to students. We consider characteristics related if their combination leads to positive influence on collaboration.

*The matrix of related characteristics* is defined as follows. Let $C$ be the set of all characteristics $C = \{c_j\},\ j = 1,2, \dots, n$. Every characteristic can be represented as a n-dimensional vector $c_j = \left(c_j^1, c_j^2, \dots, c_j^n\right)$, where:

$$c_j^i = \begin{cases} 1 & \text{if characteristic } c_j \text{ should be combined with characteristic } c_i \\ 0 & \text{if characteristic } c_j \text{ should not be combined with characteristic } c_i \end{cases} \qquad (1)$$

*The matrix of assignment of characteristics* to students is defined as follows. Let L be the set of all learners $L = \{l_k\},\ k = 1,2,\ldots,m$. Every learner can be represented as a n-dimensional vector $l_k = (l_k^1, l_k^2, \ldots, l_k^n)$, where:

$$l_k^i = \begin{cases} 1 & \text{if characteristic } c_j \text{ is typical for learner } l_k \\ 0 & \text{if characteristic } c_j \text{ is not typical for learner } l_k \end{cases} \tag{2}$$

*Calculation of clusters of learners and characteristics* is performed in several steps. First of all, three values are defined for each learner vector $l_k \in L$ and characteristic vector $c_j \in C$:

1. Value $a$ is a number of characteristics contained in both vectors.
2. Value $b$ is a number of characteristics which are typical for the current student but should not be connected with the current characteristic.
3. Value $c$ is a number of characteristics which are not typical for the current student but should be connected with the current characteristic.

Then similarity (SC) and relevance coefficient (RC) can be defined as follows:

$$\mathrm{SC}(l_k, c_j) = \frac{\mathrm{a}}{\mathrm{a+b+c}} \tag{3}$$

$$\mathrm{RC}(l_k, c_j) = \frac{\mathrm{a}}{\mathrm{a+b}} \tag{4}$$

Afterwards *Group Compatibility Matrix*, $GCM = (a_{ij}), i \in [1, n], j \in [1, m]$, is calculated as:

$$\mathrm{a_{ij}} = \begin{cases} 1 & \text{if SC} \geq \theta^{SC} \text{ and RC} \geq \theta^{RC} \\ 0 & \text{else} \end{cases} \tag{5}$$

Values $\theta^{SC}, \theta^{RC} \in \langle 0,1 \rangle$ represent minimal thresholds for similarity and relevance coefficient. Algorithm set thresholds to ones and continuously decreases them until a valid Group Compatibility Matrix (GCM) matrix is found. A GCM matrix is valid as soon as each student has at least one assigned characteristic. Finally, it is necessary to perform clustering on a GCM matrix with any array-based clustering algorithm. We used Modified Rank Order Clustering (MODROC) for our purpose.

Output data from our method is a GCM matrix in which the clusters of the students and the characteristics are concentrated along the main diagonal (see Table 1, as characteristics are used activities which are typical for particular students). Assignment of a student to a cluster of characteristics means that this student has these characteristics or these characteristics should combine with characteristics which are typical for this student. Particular study groups can be created with any combination of students from the same cluster.

We apply our method iteratively which allows us to use several matrices of related characteristics. Each matrix can represent different requirements how to combine characteristics together, i.e. a matrix of complementary characteristics or a dynamic matrix based on achieved results. The dynamic matrix can solve the problem of absence of information about attributes (in our proposal characteristics' combinations) which make collaboration effective and successful. After each group finishes task solving, its collaboration and achieved result is evaluated. Afterwards each combination between characteristics which are typical for members of this group is strengthened according to the achieved evaluation. Equally the dynamic matrix of assignment of characteristics to students can be updated according to the number of performed activities which contribute to these characteristics.

**Table 1.** An example of clustered GCM matrix acquired in the first phase of evaluation

| Characteristic activity | Student 1 | Student 2 | Student 3 | Student 4 | Student 5 |
|---|---|---|---|---|---|
| Warn of mistake | 1 | 1 | 0 | 0 | 0 |
| Accept warn of mistake | 1 | 1 | 0 | 0 | 0 |
| Write general message | 0 | 0 | 1 | 0 | 0 |
| Ask for explanation | 0 | 0 | 0 | 1 | 1 |
| Give explanation | 0 | 0 | 0 | 1 | 1 |
| Propose action | 0 | 0 | 0 | 1 | 1 |
| Accept action | 0 | 0 | 0 | 1 | 1 |
| Write praise | 0 | 0 | 0 | 1 | 0 |

## 3 Evaluation

Evaluation of our method for group formation cannot be accomplished without a collaborative environment where it is applied. Therefore, we have designed and realized the collaboration platform called *Popular Collaborative Platform – PopCorm* which is integrated within Adaptive Learning Framework ALEF [7]. It consists of four collaborative tools which are suitable for task solving in CSCL: a text editor, a graphical editor, a categorizer, and a semi-structured discussion. The categorizer is a special tool developed for solving different types of tasks in which the solution consists of one or more lists (categories). The semi-structured discussion represents a generic communication tool independent of a particular type of a task being solved. It provides 18 different types of messages (e.g. propose better solution). These different message types allow us to automatically identify student's activities. Recorded activities are used to measure the collaboration by set of seven dimensions designed rooted in studies in psychology: sustaining mutual understanding, information exchanges for problem solving, argumentation and reaching consensus, task and time management, sustaining commitment, shared task alignment and fluidity of collaboration.

We performed evaluation of our method and the collaboration platform in two phases. Firstly, we realized in February 2012 a short-term controlled experiment. The purpose of this experiment was to evaluate preconditions of the proposed method; namely, the precondition whether activities form natural clusters which influence collaboration in the positive or, on the contrary, in the negative way. Moreover, the experiment was also an opportunity to get valuable comments on the implementation of the collaboration platform. Five participants in total took part in the experiment and solved 12 tasks. The precondition was confirmed and our method was able to identify three clusters of students and activities at the end of the experiment with grouping efficacy more than 88% (see Table 1).

The second phase consisted of a long-term experiment which was realized during summer term as a part of education on the course Principles of Software Engineering at the Slovak University of Technology in Bratislava. 106 students in total participated in 208 created groups. 3 613 activities are recorded during task solving. Each activity corresponds to one sent message in the semi-structured discussion.

**Table 2.** Comparison of achieved results during the second phase of the experiment

| Groups created | Average evaluation | Feedback |
|---|---|---|
| By the proposed method | 0.459 | 4.01 |
| By the reference method (k-means clustering) | 0.392 | 3.55 |
| Randomly | 0.422 | 3.29 |

The 8-dimensional evaluation of the groups created using our method was compared with a reference method (k-means clustering) and randomly created groups (see Table 2). Groups created by our method achieved the most effective and successful collaboration in comparison with the other two types of groups. We employ ANOVA statistical model to evaluate significance of achieved results and we got p-value 0.0048. Thus, the achieved results can be considered as highly significant. Additionally, students have provided a higher explicit feedback in these groups.

## 4 Related Work and Conclusion

Several works employing Group Technology (GT) approach in CSCL domain exist. Pollalis, et al. [5] proposed a method for learning objects recommendation to student groups according to students' knowledge of relevant domain terms. Two input matrices were used. The first one represented student's knowledge; the second one represented similarity or mutual dependency of relevant domain terms which was derived from their common occurrence in the same learning object. The output was clusters of students and learning objects which were suitable for these students to learn.

Similar approach is described in [2]. The main goal of this research was to identify sets of students which use similar strategies to solve mathematical exercises. Similarly to the previous work, two matrices were calculated: the dynamic matrix representing assignment of strategies to students and the static matrix representing mutual similarity of strategies. The output was clusters of students and assigned groups of strategies. The identified clusters can be used to assign new task to particular group of students according to strategies which are familiar to the members of the group and which are suitable to solve this task as well.

As opposed to previous two works, authors in [1] considered only one matrix as input. This matrix represents teachers and subjects they teach. A hybrid grouping genetic algorithm was used to identify groups of similar subjects.

Our method considers its iterative application in contrast to the existing methods for group formation based on GT approach. This allows us to take into consideration already achieved students' results in collaboration and adjust input parameters to encourage better collaboration between students. It means that we can start the group formation process with no or minimal information about students and related characteristics. Our method then automatically learns which collaborative characteristics are typical for students and which characteristics should be combined together to achieve more effective collaboration. Moreover, automatic evaluation by seven dimensions defined according psychological studies provides immediate feedback to students and advices how to collaborate more effectively.

Our method is not limited only to the CSCL domain. It can be easily applied in other domains where dynamic groups should be created according to different user characteristics. We have successfully applied the proposed method during the experiment in collaborative learning by creating dynamic short-term study groups, which showed high potential of proposed method. It would not be possible to evaluate our method for group creation without the collaborative platform PopCorm which provides students the appropriate environment for effective task solving and automatic identification of their activities.

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